ИЗМЕРИТЕЛЬНАЯ ТЕХНИКА

Number 8, August, 1960
Translation Published March, 1961

SOVIET INSTRUMENTATION AND CONTROL TRANSLATION SERIES

Measurement Techniques

(The Soviet Journal *Izmeritel'naya Tekhnika* in English Translation)

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SOVIET INSTRUMENTATION AND CONTROL TRANSLATION SERIES

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Translated and printed by Consultants Bureau Enterprises, Inc.

Measurement Techniques

A translation of Izmeritel'naya Tekhnika, a publication of the Academy of Sciences of the USSR
Russian Original Dated August, 1960

1960, No. 8, pp. 643-726 **March, 1961**

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INTRODUCTION OF A NEW MEASUREMENT TECHNIQUE TO THE ESTABLISHMENTS OF THE ODESSA REGION

V. E. Yakhontov

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 1-2 August, 1960

One of the most important tasks of the State Inspection Laboratories of Measuring Equipment consists in encouraging, to the utmost, the introduction into our national economy of improved measurement techniques, especially of automatic control and regulation equipment in the main branches of production.

The Odessa GKL (State Inspection Laboratory) of Measuring Equipment has adopted, in this connection, several organizational measures of a technical nature.

The establishments of the Odessa Sovnarkhoz (Council of National Economy) draw up, with the assistance of the leading members of the GKL, a yearly plan for the introduction of new measuring equipment. When these plans are being compiled, with the assistance of the GKL experts, the requirements in modern measuring and control equipment and the type of instruments are specified.

On the basis of these plans, the GKL, in conjunction with the industrial departments of the Sovnarkhoz, draw up a combined plan for introducing new measuring equipment which is subject to approval by the Sovnarkhoz administration.

Our laboratory systematically controls the execution of the combined and individual plans, and sometimes takes part in distributing the measuring equipment received by the Sovnarkhoz.

By means of this planned assimilation of measuring equipment, the establishments of the Sovnarkhoz received in the second half of 1959 alone over 200 modern measuring and control devices, thus improving the technology and quality of production. In 1960, over 100 modern measuring devices were introduced in 20 establishments of the Sovnarkhoz.

At the plant for steel and hemp cables, for instance, automatic control was introduced for the heating of zinc and regulating the current in plating the wire, thus improving the quality of plating, providing a uniform covering, and raising its mechanical properties.

Recording pyrometric millivoltmeters were introduced at the Odessa tallow plant for continuous control of steam temperature in autoclave and in oil-collector heating, thus ensuring the correct technological conditions and improving the quality of production.

In the compression department of the agricultural machinery plant "October Revolution" over 20 recording flow meters, manometers, and thermometers were installed for controlling the operation of the compressors.

At the Odessa canning plant, recording manometric thermometers were introduced for controlling the sterilization of canned food, with recording manometers for controlling steam regulation and water pressure in the autoclave department.

In checking the condition of the measuring equipment and the quality of production according to the State standards and specifications and in supervising the work of the departmental inspection agencies, the GKL personnel check the amount of the available measuring and control equipment in all the areas of production and determine the requirements for modern measuring instruments.

In some of the establishments, the Laboratories also carry out special investigations of the available modern control and measuring equipment.

After the completion of the study, the establishments are provided with suggestions on the suitable new measuring equipment. A check-up on our proposals showed that during the second half of 1959 and the first quarter of 1960 over 30 technological processes had been automated and more than 200 modern instruments introduced at the plants inspected by the Laboratories. For instance, on our suggestion the "Poligrafmash" plant obtained and put into operation an instrument for complex checking of gear wheels. The mechanical plant of the Ministry of Railroads of the USSR purchased three electronic potentiometers EPD-12 for a continuous control and regulation of temperature in thermal treatment of components, thus decreasing the scrap in this section to 1/2 - 2/5 of its former amount. Instruments for automatic checking and control of the concentration of sulfuric acid and for temperature regulation in the production of simple superphosphate were introduced at the Odessa superphosphate plant. The chemical plant of the regional local industry organization introduced a noise meter for determining the acoustical properties of the phonograph record compound, a fracture testing machine for determining the mechanical strength of the compound, and a tensile strength machine for testing the tensile strength and strain of the material.

The Odessa GKL is paying considerable attention to the strengthening of the material and technical bases of departmental inspection agencies.

On the suggestion of the Laboratory the plants have purchased and put into use profilometers PCh-3, a microinterferometer MIS-11, devices for checking micron indicators of height gauge and other equipment.

Several plants have purchased a large projector, a Linnik microscope, reference piston and spring manometers, portable potentiometers, and other instruments, thus enlarging the stock of instruments and raising the quality of complicated production measurements and reference instruments.

A speedy supply of new measuring instruments to the factories is hindered by the fact that the State Planning Committee of the Ukr.SSR and the Odessa Sovnarkhoz only partially satisfy the factory requirements in control and measuring equipment, especially in recording and reference instruments.

The assimilation of new measuring equipment is also hindered by the lack of periodically issued catalogs for control and measuring instruments, with the addresses of the manufacturing plants, technical characteristics of the devices and their price.

LINEAR MEASUREMENTS

AN INTERFEROMETER FOR MEASURING LINEAR SCALES UP TO 200 MM

N. V. Trofimova

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 2-4, August, 1960

The reference of linear measures to a natural unit, that of a light wavelength, involves raising the accuracy of measuring scales and the development of an interference instrument for measuring linear scales.

The D. I. Mendeleev All-Union Scientific Research Institute of Metrology (VNIIM) has developed and produced an interference instrument for certifying standard and reference 200-mm scales of the first grade.

The instrument consists of a double Michelson interferometer with moving mirrors firmly fixed to carriages, one of which carries the linear scale under test.

This arrangement can be used for measuring linear measures in terms of wavelengths of monochromatic light by means of optical multiplication of the length, or by means of end gauges previously checked by the interference method.

The optical arrangement of the instrument for measuring scales by the Fabry-Perot method is shown in Fig. 1.

The beam of light from source 1 is focused by condenser 2 onto the collimator slot 5 which is placed in the focus of objective 6. Between the condenser and the slot there is a plate 3 which, when connected, projects the image of the slot (at an angle of 45°) onto the eyepiece 4 thus making it possible to use the tube as an autocollimator.

Mirror 7 directs the parallel rays of light through the Fabry-Perot tubular standard to the dividing block 11.

A part of the rays reflected from the dividing plate strike mirror 13, mounted in an adjustable holder of carriage 14 which can be displaced along ball-bearing guides over 200 mm.

Another part of the rays, having passed through the light-dividing layer, is directed to the reference mirror 12, mounted on a moving carriage, which has a displacement of 100 mm.

The rays of light reflected by mirrors 12 and 13 are reunited and directed by mirrors 9 and 10 to the observation system 15-18.

In order to raise the definition of the interference patterns an additional dividing plate 8a is fixed at the output of the interferometer and directs a part of the rays for a second time into the interferometer.

The image of the slot or the interference pattern is produced in the focus of objective 15 and observed through eyepieces 18 and 19, the former being a measuring eyepiece.

With a consecutive transmission of light through the multibeam (Fabry-Perot) and the double two-beam interferometers, and the displacement of the mirror carriages to distances equal or multiple of those between the reference mirrors, interference patterns are produced in the field of vision of the observation system.

The optical system of the interferometer provides an accurate displacement of the carriage with the scale under test.

The consecutively increasing multiple intervals of the Fabry-Perot standard are measured from this interference pattern.

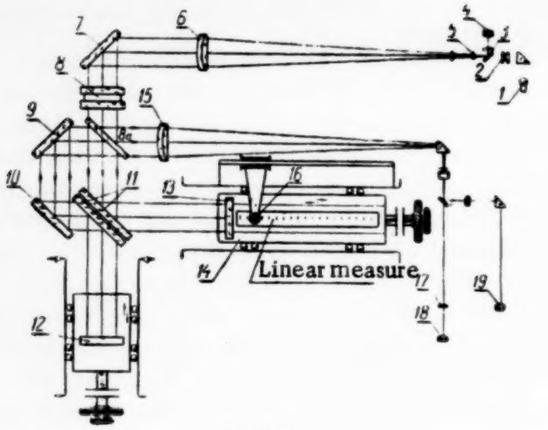


Fig. 1

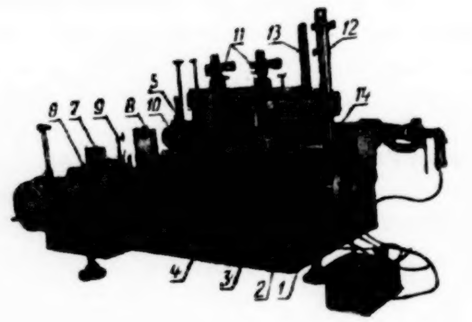


Fig. 2

Sighting and measurements of the tested scale graduations are made by means of the microdrive of carriage 14 and scale 17 of the observation system.

The black achromatic fringe of the white light interference serves as an index of the measuring scale, whose calibration unit i is varied by changing the slope of the reference mirror, and is found from the number m of interference fringes of a definite wavelength λ of a monochromatic light or a filter which covers n divisions of the scale:

$$i = \frac{m\lambda}{2n}.$$

If the tested graduations are sighted on the optical axis of microscope 16, the displacement of the achromatic fringe on the eyepiece scale 17 will provide a reading from which it will be possible to determine the relation of the length of the interval between graduations to the length of the ray path in the standard for the given ratio existing between them.

When the linear measure is compared with an end gauge the latter is fixed on the smaller carriage instead of the reference mirror.

The interference of beams reflected from mirror 13 and the free measuring surface of the gauge or the plate to which the gauge has been lapped is observed in two position of carriage 14 which correspond to the minor difference of the optical path of rays in the arms of the two-beam interferometer.

On the basis of the difference in the readings and the length of the end gauge, which has been measured previously by the interference method, the length of the graduation interval can be determined.

When the measurements are made in monochromatic light the length of the graduation is established from the difference of the fractional orders of interference which correspond to the beginning and the end graduations of the measure under test.

Figure 2 shows the appearance of the instrument without its thermal insulation cover. The upper surface of the chassis 1 carries the mechanical and optical units of the instrument: the main carriage 2 with the adjustable mirror 5 and platform 3 for the fixing of the tested scale 4, carriage 6 with the reference mirror 7, the dividing plates 8, auxiliary mirror 9, the collimator objective of the observation system, and a table with an opening carrying the tubular standard 10.

The same chassis carries guiding rails parallel to the travel of the main carriage and made to support two microscopes 11.

The microscope tubes have special holders which provide a rough displacement of the microscopes along the axis of the linear measure. Fine displacement is achieved by means of the microscrew. A vertical displacement of the microscope is provided for focusing the graduations of the scale. To the right of the rail a

bracket is mounted with a telescope which has two eyepieces, one of which (12) is used for measuring and the other (13) for observing the image of the slot when adjusting the mirrors and the standard.

Collimator 14 with the illuminator is mounted on a bracket fixed to the side wall of the chassis outside the thermal insulation cover of the instrument. In order to obtain an accurate displacement of the mirror carriages, hinged guides are used.

Deviations from the linearity of movement of the main carriage of the instrument along its 200-mm run does not exceed 1.3" when it is adjusted by means of the autocollimator (type PKG-2 with graduations of 0.25") or by interference methods (transposed fringes).

The eyepiece calibration scale of the observation system is maintained constant during measurements by the linearity of the carriage guides and the choice of the interference wedge value α so that $\alpha \gg \Delta\alpha$, where $\Delta\alpha$ is the deviation from linearity of the carriage guides.

The linear measure is fixed to the upper platform of the table by means of supports which fit into grooves in the platform.

The interference standard is fixed in a special holder mounted on the table.

The instrument is encased in a thermostatically controlled jacket made of sheet aluminum with a lagged lining. The thermostatic control provides a uniform temperature field within the limit of 0.01°C.

The illuminating system, the table control knobs and the eyepiece adjusting levers are placed outside the jacket.

Tests of the interference comparator showed the possibility of determining scale lengths with an error of the order of 0.05-0.10 μ. Moreover the divergence of various internal comparisons remains within the limits of 0.03-0.06 μ.

Experiments in measuring linear measures in terms of wavelengths were carried out by the white light interference method and a visual sighting of graduations.

In order to increase the accuracy of sighting, raise the productivity and attain a greater objectivity of measurement the instrument is being equipped with a photoelectric microscope.

In the future a complete automation of measurements in monochromatic light may be achieved by using a counter of interference fringes in combination with the photoelectric microscope.

Conclusions. The assimilation of interference instruments for calibrating linear measures of length provides, in addition to raising the accuracy of measurements, a practical basis for referring all linear measurements to a light wavelength.

LITERATURE CITED

1. M. L. Brzhezinskii, Trudy VNIIM 6, 67 (1955).

MEASUREMENT OF LARGE DIAMETERS BY THE GIRDLING METHOD

A. D. Rubinov

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 4-6, August, 1960

Measurements of external diameters above 2000-2500 mm far removed from the ends of details, is at present carried out almost exclusively by means of girdling the component with tape measures or special metal tapes.

An analysis of measurements made by means of tape measures and special tapes shows that the latter provides a considerably higher accuracy [1].

Thus, when special tapes are used, it is possible to measure components with a 2a grade of accuracy; when reference tape measures are used, with a grade 3 accuracy; and when ordinary tape measures are used, with only a grade 5 accuracy.

Nevertheless, in factories, tape measures are mainly used. This is due to the fact that a given tape can only be used for checking a detail of a certain diameter. It is impossible to use the same tape for checking different diameters, since the gap between the ends of the tape must be small enough to be able to measure it with a feeler gauge, and it is impossible to measure, instead of the gap, the distance between the sides of the set-squares, since they are not parallel (the angle between them depends on the size of the gap).

Moreover, the use of special tapes is made difficult because they require special measuring and stretching devices.

When a tape with rollers is used the distance between the circumferences of the rollers (Fig. 1) can be determined with an instrument which makes it possible to measure any size external diameters exceeding 2000 mm.

This instrument is made up of a micrometer with a frame of a changed shaped and an additional device which provides a constant tensioning of the tape.

The instrument consists of a frame bracket 4, a micrometer head 3 with interchangeable measuring rods 5 (of a micrometer depth gauge) and a carriage 10 with a tensioning device.

The measuring rod of the micrometer passes between the jaws of the tensioning device lever 8 and rests against the righthand side roller of tape 18 The left hand side roller 17 rests against the solid jaw of the frame. The micrometer head is set in its zero position by means of special setting or block gauges. The tensioning device is mounted on carriage 10 which can be displaced along the frame and fixed in any position by means of a set screw 2 and nut 1.

The tape is tensioned by means of screw 11 whose movement is transmitted by means of lever 8, with ball 9 and roller 6 at its ends to the right hand side roller of the measuring tape. The ratio of the lever arms can be made 1:1 or 2:1.

The lever revolves about axle 7 which passes through longitudinal slots in the sides of the frame and the top end of the lever passes through vertical slots of the frame and the carriage.

A constant tension is provided by spring 13 which presses cap 12 against cap 16. Cap 12 is connected by means of pin 14 to screw 11 and can move along the screw axis within small limits (in the screw slot). Between caps 12 and 16 there are two balls 15 serving to transmit the movement of cap 16, which is turned by hand, to cap 12 and screw 11. When the tensioning of the tape becomes equal to the spring tension, screw 11 will stop turning, since any further turning of cap 16 will displace cap 12 to the right and the balls will come out of their sockets and cap 16 will become disengaged.

The measuring procedure by means of this instrument consists of the following: the detail under test is girdled by the tape, lock nut 1 is released. The frame is placed over the rollers of the tape in such a manner that the solid jaw of the frame rests against the left hand side tape roller. Carriage 10 is moved along the frame until roller 6 of lever 8 touches the right hand side tape roller, and then the carriage is secured in that position; screw 11 is then turned by means of cap 16 until the latter begins to slip; next the micrometer thimble is rotated by means of its ratchet until the measuring rod presses against the right hand side roller when a reading is taken; the diameter of the detail under test is determined from a formula whose derivation is given below.

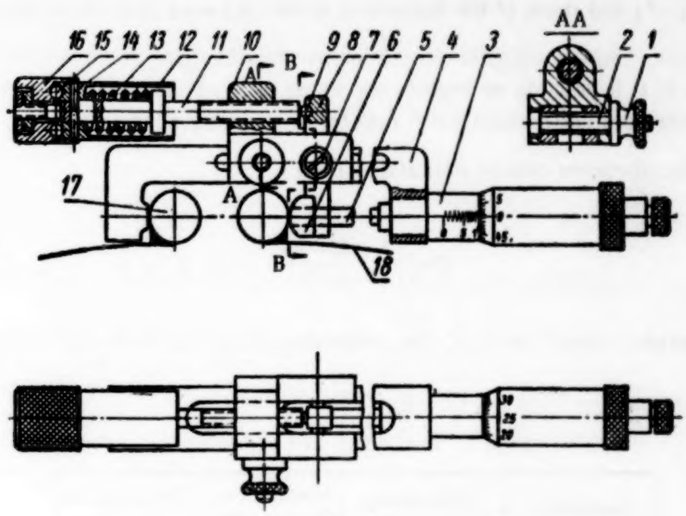


Fig. 1

In calibrating the tape, distance L is determined (Fig. 2a). When the detail is girdled by the tape this distance corresponds to the larger arc of the detail's circumference between points A and B (Fig. 2b). The circumference of the detail will be:

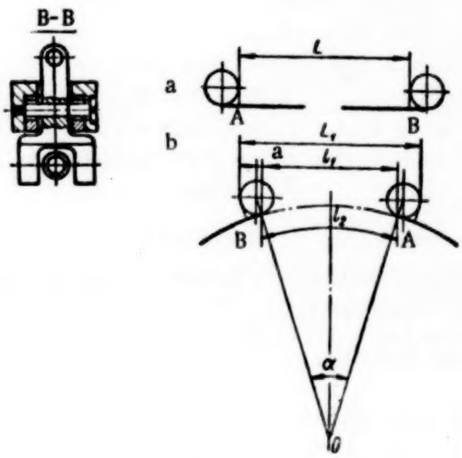


Fig. 2

$$l_{dt} = L + d + l_2,$$

where L is the length of the tape, mm (the length of the larger arc between points A and B); $d = (d_1 + d_2)\ 2$; d_1 and d_2 are the diameters of the rollers, mm; l_2 - the length of the arc between the points of contact of the rollers with the surface of the detail.

By means of the instrument, the following dimension is determined:

$$L_1 = l_1 + d + 2a,$$

where l_1 is the length of the chord which corresponds to arc l_2, in mm.

Whence

$$l_{dt} = L + L_1 - 2a + l_2 - l_1.$$

The value of 2a is determined from the formula:

$$2a = d \sin \frac{\alpha}{2} = d \frac{L_1 - d}{D + d}.$$

In order to obtain 2a it is first necessary to calculate the approximate value of the diameter from:

$$D \simeq \frac{L + L_1}{\pi},$$

and then substitute the value thus found for D.

The values of 2a, $l_2 - l_1$ and those of the diameters to be measured depend on the value of angle α and that of the diameter.

For angles less than 6° it is possible to neglect the value of $l_2 - l_1$ since the error $(l_2 - l_1)$ thus committed in determining the diameter does not exceed 0.013 mm for each meter of the diameter.

Then the value of the diameter can be calculated from

$$D = \frac{L + L_1 - 2a}{\pi}.$$

If the value of the angle is taken to be 6°, the measuring limits for each tape and for each instrument can be set as follows:

Diameters to be measured, mm	Measuring range for each tape, mm	Numbers of instruments (which differ by the length of the frame)	Distances between meas. surfaces of micrometer frame, mm
2000–3000	30	1	126
3000–4000	50	2	235
4000–5000	65		
5000–6000	80	3	345
over 6000	100		

If from the point of view of the convenience of use it is considered advisable to increase the range covered by each tape and hence increase angle α it will no longer be possible to neglect $l_2 - l_1$.

In this case the values of l_2 and l_1 should be determined from the formulas:

$$l_2 = \pi D \frac{\alpha}{360} = 0{,}01745 D \frac{\alpha}{2}.$$

$$l_1 = D \sin \frac{\alpha}{2}.$$

It is possible to assume in computations that

$$\sin \frac{\alpha}{2} = \frac{L_1 - d}{D}.$$

In order to simplify the calculations of 2a and $l_2 - l_1$ their values can be determined in advance for various values of L_1 and tabulated.

The total error of the above method of measurement consists of the following components: the error in measuring the length of the tape; the error in stretching the tape; temperature errors; errors in measuring the distance between the rollers by means of the instrument; the error in determining the value of 2a, and errors arising when the difference $l_2 - l_1$ is neglected.

Having analyzed the components and determined by known methods the total error, we found that its maximum value is ± 15 μ for each meter of the measured diameter. Thus the instrument can be used for measuring details of grade 2a and lower.

LITERATURE CITED

1. A. D. Rubinov, Measurement of Large Dimensions in Engineering [in Russian] (Mashgiz, Moscow-Leningrad, 1959) 2nd ed.

CORRECTIONS TO HOLE GAUGE READINGS WHEN MEASURING LARGE VERTICAL DIMENSIONS

I. P. Vaganov

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 6-8, August, 1960

The most commonly used micrometric hole gauges for measuring large dimensions in our heavy engineering industry are those of the detachable cylindrical (type ChIZ) and cigar-shaped gauges (type LMZ of the "Elektrosila" plant).

It is known that the effective length of a hole gauge decreases in the vertical position owing to the effect of its own weight [1]. The numerical value of this decrease has not been, as far as we know, determined by anyone experimentally owing to the lack of measuring devices which would provide sufficiently accurate height measurements exceeding 1000 mm. As a first approximation it is possible to determine this value as the difference between the dimensions of a hole gauge measured in a horizontal position on an end measuring machine, and those obtained first with the effort of an optimeter exerted on it and then with an effort equal to half the weight of the hole gauge.

The Sverdlovsk Branch of the All-Union Scientific Research Institute of Metrology in cooperation with the Central Test Laboratory of the Uralmash plant carried out these experiments according to the following technique. The hole gauge was placed on the supports of the machine and its dimensions measured. Next, the hole gauge was compressed along its axis in the direction of the tailstock by means of a system of cables and weights, and its dimension was measured again.

The experimental data obtained from determining the variations in the length of the hole gauge with respect to the measuring range and the value of the effort exerted in compressing the gauge along its axis are shown in Table 1.

It was then also shown that the variation in the position of the resting points had hardly any effect on the measurement results.

In addition to the shortening of the hole gauge due to the effect of its own weight when measuring large vertical dimensions, the tip and microhead of the hole gauge with their working spherical surfaces sink into the measured details thus increasing the reading of the instrument.

The numerical value of correction a_1 for the flattening out of the spherical surfaces of the tip and the microhead, and the compression of the detail under the compression effort P along the axis of the hole gauge, can be calculated from the modified and simplified Hertz formula:

$$a_1 = 3.825 \sqrt[3]{\frac{P^2}{2R}}, \tag{1}$$

where P is the compressive effort, i.e., the weight of the hole gauge, kg-wt; R - the radius of curvature of the measuring surface of the hole gauge tip, mm.

In addition, the actual length of the vertically placed hole gauge decreases by the amount of $(na_2/2)$ μ, where a_2 is the value by which the two extension pieces with spherical surfaces (radius of curvature R_2 = 50 mm)

TABLE 1

Loading along the axis of the hole gauge, kg-wt	Dimensions, mm									
	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500
	Mean decrease in the length of the hole gauge when compressed along its axis, μ									
Cigar-shaped extension pieces UZTM										
2	2	2			3	4	4			
4	4	4			7	8	9			11
9	8	9			16	16	20		19	23
11	10	11			20	21	24		23	27
Micrometric hole gauge ChIZ										
2		4	5	5	6	7	7	9		
4		9	11	13	15	16	19	21		
6		14	17	20	24	26	27	33		
8		19	24	27	32	36	38	44		

TABLE 2

Measuring means		Dimensions, mm								
		1000	1500	2000	2500	3000	3500	4000	5000	5500
Cigar-shaped extension pieces UZTM	P, kg-wt	2,1	2.5	3.0	3.5	3.9	4.5	5.0	6.5	7.1
	F, mm^2	85	90	95	100	110	115	118	126	130
	Δy_1, μ	1.6	1,9	2.6	3.4	4,3	5.3	6,6	7.6	9.9
	Δy_2, μ	1,2	1.6	2.3	3,0	3.6	4.3	5,3	7.7	8,8
	Corrections, μ	1	2	2,5	3	4	5	6	8	9
Micrometric hole gauge ChIZ 150–4000 mm	P, kg-wt	2.7	3,7	4,8	5.8	6.9	7.9	9,0		
	Δy_1, μ	4,9	7,9	11,4	15,6	20.6	26,1	31,3		
	Δy_2, μ	4,0	5.4	9,5	12,9	17,2	21,9	27,3		
	Corr., μ	4	7	10	14	19	24	29		

approach each other; n is the number of contacts between the extension pieces, the microhead and the extension piece and the tip and the extension piece.

The numerical value of a_2 is found from the formula:

$$a_2 = 2.409 \sqrt[3]{\frac{P^2}{2R}}. \qquad (2)$$

Thus, in a general case, the total correction Δy will consist of the following components: 1) elastic compression of the hole gauge $\Delta\alpha_e$ under the effect of its weight; 2) the flattening out a_1 of the spherical surface of the tip and deformation in the surface of the measured detail; 3) the flattening out of the spherical surfaces of the extension pieces, the head and the tip na_2 at the points of their contacts.

Table 2 gives correction $\Delta y_1 = \frac{\Delta\alpha_e + a_1 + na_2}{2}$, which is based on experimental data (correction $\Delta\alpha_e$ was interpolated from Table 1 on the basis of weight P of the hole gauge), correction $\Delta y_2 = \Delta\alpha_m + \frac{a_1 + na_2}{2}$ was determined from theoretical considerations [1] where $\Delta\alpha_m = PL/2EF$; P is the weight of the hole gauge; L - the dimension of the hole gauge; E - the modulus of elasticity equal for steel to $2 \cdot 10^4$ kg-wt/mm^2; F - the cross sectional area of the hole gauge measuring rod in mm^2; (in the micrometric hole gauge ChIZ 150-4000 mm F = 50 mm).

The comparison of the correction Δy_1 and Δy_2 shows that the calculated and experimental data both for the cigar-shaped extension pieces UZTM and the micrometric hole gauges ChIZ on the whole agree satisfactorily with each other.

It is obvious that for each type and construction of a hole gauge there will be a different correction Δy which it will be necessary to determine experimentally by the method outlined above.

Table 2 shows that it will be necessary to apply corrections when the measured value is equal to 1000 mm or more, if a hole gauge ChIZ 150-4000 mm is used, and when it is 3000 mm if a cigar-shaped hole gauge is used.

In connection with the study of the question of measuring by means of hole gauges large vertical dimensions, there also arises the problem of determining the tension σ_{max} at the point of contact of the detail with the measuring surface of the vertically placed hole gauge. The knowledge of the value of σ_{max} at the point of contact and its comparison with the elastic limit of the measured detail provides the possibility of recommending the measurement by means of hole gauges of vertical dimensions of details made of certain materials.

When vertical dimensions are measured with a hole gauge, it can touch with its lower end (the measuring surface of the tip) either a plane when measuring a distance between two planes, or a cylindrical surface, when measuring the internal diameter of a cylinder. In the first instance the value of the largest tension in the center of the touching circle can be expressed by formula [1]

$$\sigma_{max} = 0.388 \sqrt{\frac{PE^2}{R_1^2}}. \qquad (3)$$

TABLE 3

Measuring means	Dimensions, mm								
	1000	1500	2000	2500	3000	3500	4000	5000	5500
	Values of σ_{max}, kg-wt/mm²								
Cigar-shaped extension pieces UZTM	18	19	21	22	23	24	25	27	27
Micrometric hole gauges ChIZ 150-4000 mm	20	23	24	26	27	29	30		

When a vertical distance between cylinders is measured:

$$\sigma_{max}=0.4\sqrt[3]{\frac{PE^2\,(R_1+R_2)^2}{(R_1R_2)^2}} \qquad (4')$$

where R_1 is the radius of curvature of the hole gauge tip (according to GOST 10-58 it is equal for large dimensions on an average to 90 mm).

In the second instance, the value of the largest tensions in the center of the elliptical touching surface is expressed by the formula:

$$\sigma_{max}=0.4\sqrt[3]{\frac{PE^2\,(R_2-R_1)^2}{(R_1R_2)^2}}. \qquad (4)$$

where R_2 is the radius of curvature of the cylindrical (measured) surface.

Calculations from (3) and (4) for the case of the cigar-shaped and the cylindrical hole gauges provide values of σ_{max} which are very close to each other.

Hence, values of σ_{max} obtained from (3) can be safely used for calculating the maximum tensions at the point of contact of the hole gauge tip and the detail. These values are given in Table 3.

It will be seen from Table 3 that the values of the largest pressures at the points of contact of the hole gauge with the detail when measuring vertical dimensions are large. Hence the measurement of vertical dimensions by means of hole gauges which are supplied with spherical measuring surfaces is only possible for details which have a compression strength not less than 30 kg-wt/mm^2 (i.e., cast iron, steel, brass). If the details are made of other materials the measuring surfaces of the tip and micrometric head of the hole gauge must be flat.

LITERATURE CITED

1. N. M. Belyaev, Resistance of Materials [in Russian] (GITTL, Moscow, 1958).

MEASURING THE THICKNESS OF THE CUTTING PRODUCED BY A ROTARY EXCAVATOR SCOOP

V. Yu. Chudnovskii

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 8-10, August, 1960

The measurement of the linear dimension of the cutting produced by a rotary excavator scoop is required, both for experimental investigations and for the working of the machine, in order to be able to provide its optimum operating conditions.

In view of the absence of any work on the measurement of the cutting dimensions it is useful to examine this problem.

Rotary excavators with a crane-arm feed mechanism either have telescopic or solid arms.

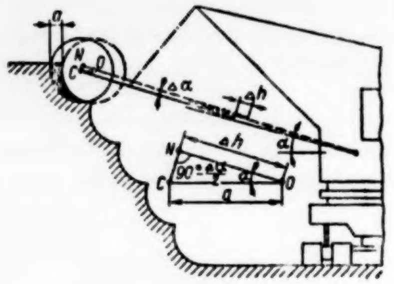


Fig. 1.

Figure 1 shows a rotary excavator with a telescopic arm. The horizontal movement of a rotor of such an excavator by the thickness of the cutting a, is attained by the forward displacement of the front girder of the arm by the amount of Δh, and by changing the horizontal slope angle α of the arm by an angle $\Delta\alpha$.

The thickness of the cutting can be found from the triangle of the rotor axle displacement ONC:

$$a = \frac{\cos\frac{\Delta\alpha}{2}}{\cos\alpha\cos\frac{\Delta\alpha}{2} - \sin\alpha\sin\frac{\Delta\alpha}{2}}\Delta h. \tag{1}$$

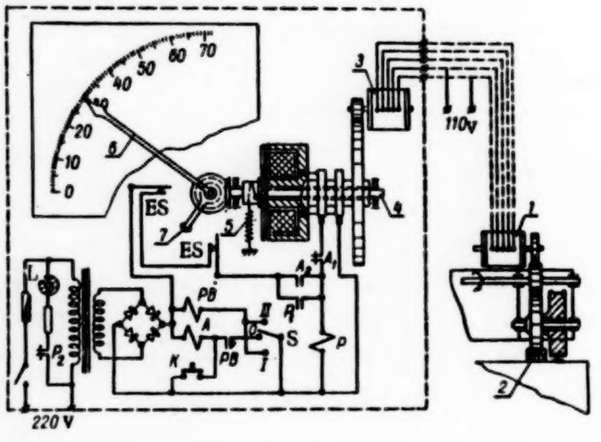


Fig. 2.

The horizontal slope angle α should not vary by more than $\pm 16°$ owing to the operating conditions of the belt conveyor which is mounted on the crane arm. The values of the angle $\Delta\alpha$ do not exceed in practice 1°; this is due to the fact that the thickness of the cutting even for large excavators does not exceed 0.5-0.6 m and the arms are some 20 to 100 m long. Hence it is possible to write with a sufficient degree of accuracy that

$$\cos\frac{\Delta\alpha}{2} = 1 \quad \text{and} \quad \sin\frac{\Delta\alpha}{2} = 0,$$

then

$$a = \frac{1}{\cos\alpha}\Delta h. \tag{2}$$

Calculations show that by determining a from (2) instead of (1) an error not exceeding $\pm 0.25\%$. Hence it is possible to insert in (2) the mean value of $\overline{1/\cos\alpha}$ in the interval $\alpha = \pm 16°$. Then

$$a = 1.02\Delta h. \tag{3}$$

On the basis of the linear relationship in (3) a device was designed which provides, by means of selsyns a remote recording of the cutting thickness from the value of the arm displacement. The device (Fig. 2) consists of a transducer 1 which records the displacement of the arm, and consists of selsyn SS-404, and an indicating instrument which is mounted on the excavator control board.

Selsyn 1 is connected by means of a rack and pinion transmission 2 with the arm feeding mechanism. The transmitting selsyn is connected by means of a cable to the receiving selsyn 3 (also type SS-404) which is mounted on the frame of the instrument. The axle of the receiving selsyn is connected by means of two gears to an electromagnetic clutch which rotates freely on axle 4 which carries the disk armature of the clutch. Axle 4 is supplied with a return spring 5 and connected by means of a bevel gear to the spindle of the indicating pointer 6.

The electromagnetic clutch, relay A, and the time relay PB, which form part of the electrical circuit, are fed from the 220 v ac mains through a step down transformer and bridge type rectifier consisting of four DGTs-23 germanium diodes. The clutch winding is fed through slip rings and brushes.

The device operates in the following manner:

At the end of a slope when the reversing mechanism is operated, which is always done before the forward movement of the arm is started, the operator sets the combined turning drive control switch into the neutral position.

Moreover, the switch which is coupled with the combined switch is then moved from position I ("turn left") or position II ("turn right") to the "O" position. This operation disconnects time relay PB, whose contacts remain closed for another 0.5-0.6 sec, and connects relay A, whose normally open (n.o.) contact A_1 disconnects the electromagnetic clutch supply circuit. At the instant the clutch is disconnected, spring 5 returns pointer 6 to the zero position.

After the lapse of the time delay the contacts of relay PB open and de-energize relay A whose normally open contact A_1, switches in the clutch, thus preparing the device for measurements. Having completed the reversing action, the operator connects the arm driving mechanism. When the arm is advanced, the axle of the transmitting selsyns turns by an amount proportional to this movement. The receiving selsyn turns through the same angle displacing pointer 6 over the measuring scale. At each reversal of the turning mechanism these actions are repeated, thus providing an automatic setting of the pointer to zero and a measurement of the thickness of each cutting starting directly from zero.

The range of the measuring scale has been set at 70 cm in order to obtain the required accuracy of reading. In order to protect the instrument from damage when the arm is swung out in a nonoperating condition beyond this limit, the circuit includes end switches with normally open contacts ES_1, and ES_2 which are placed in the clutch winding circuit, and also a cam 7 fixed to the spindle of pointer 6 and relay P.

When the pointer exceeds the scale limit cam 7 disconnects contacts ES_1 (or ES_2 depending on the direction of its movement). This action disconnects relay P whose normally open contact P_1 de-energizes the clutch, and the pointer is returned to zero under the action of spring 5 (this position is fixed by the pointer cam 7 resting against contact ES_2). Simultaneously, the normally closed contact P_2 connects lamp L, which signals the disconnection of the device.

When the rotor has been placed in the slope the device is reset by pressing the key switch button K. The pressing of this button returns, if required, the pointer to its zero position.

The above device was developed by the author at the Dnepropetrovsk Mining Institute and installed on a large rotor excavator with a telescopic arm and a productivity of 2100 m^3/hr. This excavator with the device, operated successfully at the Yurkovo pit, since July, 1959.

The device for measuring the thickness of the cutting of telescopic arm excavators can also be used with excavators which have a single arm; for instance, with the rotor excavators of the Novokramatorsk Engineering plant which have a capacity of 3000 m^3/hr.

In this case the required measuring accuracy is obtained by making the gear ratio of the kinematic chain which connects the transmitting selsyn to the pointer mechanism variable, bearing a linear relation to the angle of slope of the rotor arm to the horizontal plane. The latter is achieved by connecting into the kinematic chain a mechanical speed changer, whose controlling shaft is automatically set by a selsyn which is electrically connected to the selsyn transmitting the horizontal slope angle of the excavator arm.

LUBRICATION FOR GAUGE BLOCKS

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 10, August, 1960

Z. I. Mochenova (D. I. Mendeleev All-Union Scientific Research Institute of Metrology) suggests a method to increase the life of gauge blocks by covering the measuring surfaces of gauges, before use, with a lubricating layer consisting of aviation gasoline and acid-free vaseline (10%). When the gasoline has evaporated, it leaves on the surface of the gauge a thin lubricating layer which hardly affects the dimensions of the gauges, and improves the sliding of the measuring surfaces of the instruments under test over the gauges.

The method was checked by experiments and found to be satisfactory.

The suggestion has been approved by the Office for the Promotion of Efficiency and Inventions (BRIZ) of the Committee of Standards, Measures and Measuring Instruments.

MECHANICAL MEASUREMENTS

DETERMINING THE ACCELERATION DUE TO GRAVITY AT THE LOCATION OF THE VNIIM (ALL-UNION SCIENTIFIC RESEARCH INSTITUTE OF METROLOGY)

K. N. Egorov and A. I. Martsinyak

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 10-11, August, 1960

From 1947 to 1960, the D. I. Mendeleev All-Union Scientific Research Institute of Metrology worked on the determination of the absolute value of the acceleration due to gravity (g) by three independent methods: swinging pendulums, simultaneous fall of bodies (Agaletskii's method) and a free fall of a quartz rod (Martsinyak's method).

Method of determination	Experimenter's name	No. of values obtained	Mean value of g, cm/sec2	Root-mean-square error, meas, cm/-/sec²
Five quartz swinging pendulums of equal mass but different lengths	Agaletskii and Egorov	207	981.9188	0.0004
Combined falling of bodies	Agaletskii and Egorov	21	981.9215	0.0016
Free falling of a quartz rod	Martsinyak	17	981.9229	0.0013

The main work was completed by 1956 [1,2,3] Its results were discussed at the 11th General Assembly of the International Goedetic and Geophysical Union (Toronto, September, 1957) which noted their great scientific value [4].

Between 1957 and 1959 two new values of g were obtained, by means of twp quartz swinging pendulums and the free falling rod method.

The pendulums had the same mass, but different lengths. These pendulums were used in 1956, but their mounting plates, made of pyrex glass, were replaced by fused quartz plates. This change was made in order to show that the results did not depend on the material of the plates, providing the oscillations of the swinging pendulums occurred on the same knife edge bearing, and the differential method proposed a long time ago by Bessel was used in order to eliminate the contact forces in the kinematic couple of the bearing and prevent the swinging of the stand.

In order to obtain greater accuracy the pendulum oscillations were kept within a strictly defined interval of amplitudes, and a bearing with a knife edge was used, which had a sufficiently regular cylindrical surface obtained by running in the edge by means of the pendulum oscillations during 100 hr., with a load exceeding the normal by 40%.

From the observation of the oscillations of the quartz swinging pendulums Nos. 4 and 6 the value of g was fixed at $g = 981.9193$ cm/sec^2.

Taking into account all the corrections the effective length of pendulum No. 4 was $L = 39.95700 \pm 0.000013$ cm and that of No. 6 $L = 74.91715 \pm 0.00002$ cm.

The determination of g by means of the falling quartz rod consisted of the following: while the rod is falling in the vacuum chamber both its flat sides, which are covered with photographic emulsion, are illuminated over their entire length through small slots by short periodic flashes of pulsed lamps. The frequency of these flashes is synchronized by a frequency standard. After its fall and developing the rod bears a series of transverse lines the distance between which increase according to the law of a free falling body. By measuring the distances between the lines and knowing the corresponding time intervals, it is possible to determine the value

of g by means of the least squares methods [2, 3, 5].

The equipment was improved in 1958 with the object of obtaining clearer lines.

By means of the improved apparatus 11 new values of g were obtained in 1959 at a flashing frequency of 250 cps. These values were added to the six values obtained in 1956 at the frequency of 250 cps., and the mean value of g was determined as $g = 981.9229$ cm/ sec^2. The remaining 9 values of g obtained in 1956 were not included since they were determined with a smaller degree of accuracy in the initial stages of the experiment [3].

In 1956 the absolute value of g was determined by the combination of freely and nonfreely falling bodies. This method consisted in registering, by means of periodic electrical pulses, simultaneously the falling of a nonfree short chamber with respect to ground and that of a free body inside that chamber with respect to its walls. By this means 21 values of g were obtained [1, 3] which were used for determining the acceleration due to gravity.

Thus by means of three independent methods in 1956-59 altogether 245 separate values of g were obtained. The mean values are given in the Table.

A statistical analysis has shown that all the 245 values belong to a single normal set with a confidence probability of 0.997. Hence, the absolute value of acceleration due to gravity for the location of the VNIIM was determined as the mean weighted value of the three independent values. The weighting for each value was taken to be inversely proportional to the square of the root-mean-square error of measurement. This mean weighted value is equal to $g = 981.9192$ cm/ sec^2

The error of the above value calculated as a limiting error with a confidence probability of 0.997 is equal to 0.003 cm/ sec^2.

On the basis of the above VNIIM considered it possible to adopt for metrological purposes a value of $g_{VNIIM} = 981.919 \pm 0.003$ cm/ sec^2.

The coordinates of the VNIIM location (Leningrad) are: latitude $\varphi = 59°55'06"$ and longitude $\lambda = +2.7"$ to the west of Pulkovo, and the height above sea level is H = 3.5 m.

LITERATURE CITED

1. P. N. Agaletskii and K. N. Egorov, Ismeritel'naya Tekh., 6 (1956)
2. A. I. Martsinyak, Ismeritel'naya Tekh. 5 (1956)
3. P. N. Agaletskii, K. N. Egorov and A. I. Martsinyak, Trudy VNIIM, 32, 92 (1958).
4. K. N. Egorov, Ismeritel'naya Tekh. 1 (1959).
4. A. I. Martsinyak, Trudy VNIIM, 37, 97 (1959)

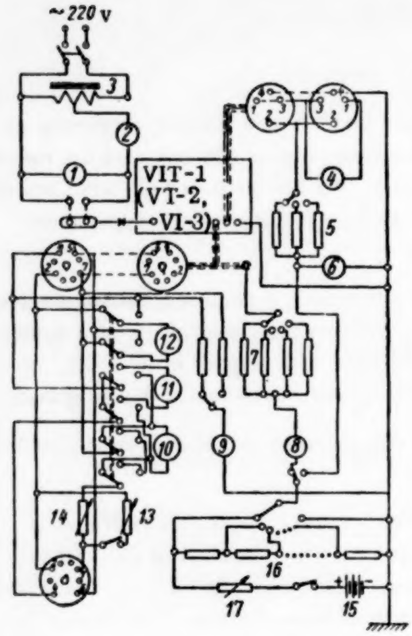
A REFERENCE EQUIPMENT FOR CHECKING VACUUM GAUGE MEASURING UNITS

A. V. Eryukhin

Translated from Izmeritel'naya Tekhinika, No. 8, pp. 11-12, August, 1960

Under normal conditions the manometric tubes and measuring units of ionization and thermocouple vacuum guages should be interchangeable, since they often have to be replaced when they fail and sometimes the same measuring unit has to be used with different manometric tubes, etc. The existing technical conditions do not provide for separate testing of measuring units and thus do not make them completely interchangeable.

In the specifications of manometric tubes no tolerances exist for the variations of heater parameters and measuring units have no specified normal supply requirements for the above heater parameter variations. The measuring units are tested at the plant with any available manometric tubes; thus a normal operation of a unit with a certain manometric tube is not a guarantee that it will operate with another tube or the tube in another unit.



Schematic of reference equipment circuit for checking measuring units of vacuum gauges. Supply unit- 1) voltmeter; 2) ammeter; 3) autotransformer. Equipment for checking the measuring unit of a thermocouple vacuum gauge: 4) milliameter; 5) resistances substituting those of the thermocouple proper; 6) millivoltmeter. Equipment for checking the measuring unit of an ionization vacuum gauge: 7) a set of resistances; 8) multirange microammeter; 9) microammeter used as a high-resistance voltmeter; 10) ammeter; 11) milliammeter; 12) voltmeter for measuring in an ac circuit; 13 and 14) a shunting and building-out resistors in the manometric tube cathode circuit. Source of a dc controlled voltage; 15) storage battery; 16) divider; 17) resistance box.

The specifications for thermocouple vacuum gauges do not provide for separate testing of the thermal emf for nominal and limiting values of the thermocouple resistance; hence, the accuracy of the supplementary resistance is not checked, thus making systematic measuring errors in the unit quite possible.

An analysis of errors in measuring units of thermoucouple and ionization vacuum gauges have shown that the maximum errors in the lower parts of the scale can exceed several times the specified errors of 5%.

Special investigations of manometric tubes and measuring units of thermocouple and ionization vacuum gauges led to the conclusion that separate testing of measuring units is indispensible for the solution of the above mentioned task of making them interchangeable. Such testing requires the supplementation of the existing specifications by tolerances for the manometric tube heater parameters and error limits for various parts of the measuring unit scales.

Testing according to such specifications requires special measuring equipment which must contain not only reference instruments for checking instruments which are contained in the measuring units, but also special sources of supplies which replace the manometric tubes, and instruments for checking the electrical operating conditions, provided for the manometric tubes, by the measuring units. Such equipment has been developed in the vacuum measuring laboratory of the VNIIM.

This equipment (see Figure) provides testing of measuring units of ionization and thermocouple vacuum gauges in such a manner as to make them interchangeable for manometric tubes as well as all the electrical testing specified for vacuum gauges.

For checking measuring units of thermocouple vacuum gauges, the thermal emf of thermocouples is replaced by a voltage obtained from divider 16 and reduced to the drop across resistor 5, which replaces the resistance of the thermocouple. Resistor 5 can be varied within the limits specified for the resistance of thermocouples.

For checking the ionization vacuum gauge amplifier, divider 16 is used, which supplies the required value of current for replacing the ionization current. Moreover, the greater part of the voltage drop occurs across one of the resistors 7, thus preventing the shunting of the amplifier input by a low resistance of the divider.

The operation of the emission current-stabilizer in the ionization vacuum gauge is checked by means of a shunting and building-out resistance in the cathode circuit (resistors 13 and 14 respectively) which provide a variation of the heater current and voltage within the required limits.

The measuring limits and errors in the values measured by the reference equipment make it possible to test the measuring units of vacuum gauges types VIT-1, VIT-1P, VT-2, VT-2P, VI-3 and VI-3P.

The operation of the emission current stabilizer of an ionization vacuum gauge was studied by means of this equipment for various values of the supply voltage, and the limits in the variations of the manometric tube heater parameters and those of the supply voltage for which a normal emission current stabilization can be provided was established.

Conclusions. The operation of the equipment showed that it is convenient both for normal testing and for studies required in reference testing of the equipment.

CONSTANT FORCED RETURN IN MOVING ELEMENTS OF MEASURING INSTRUMENTS

N. P. Zakaznov

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 13, August, 1960

Moving elements of measuring instruments with a reversed motion introduce errors due to variation produced by backlash.

In linear reversed motion the accuracy of operation can be raised by using a spring device which provides a constant reversing force irrespective of the mutual position of the moving elements. This device (Fig 1.) consists of a gear 1, a toothed rack 2, connected to the moving elements, and a grooved roller 3, coupled by a flexible cord 4 to spring 5, which is fixed to the moving element. The effective radius of the roller is equal to that of the pitch diameter of gear 1.

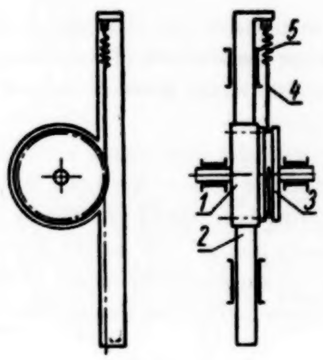


Fig. 1

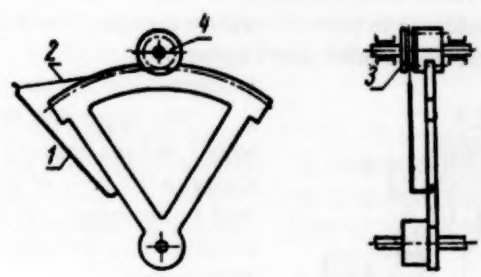


Fig. 2

When rack 2 is displaced,the end of the spring to which cord 4 is attached remains stationary, since the cord is wound over the roller or unwound from it by the amount of the rack displacement. Thus the tension of the spring remains constant.

Spring 5 has a tension sufficient to overcome friction in the kinematic chain and provide the required value of contact pressure.

In addition to eliminating backlash this device provides a stable relative position of the links of this system.

In measuring instruments using a geared transmission from the sensing element to the pointer a spiral hair spring is used for eliminating backlash.

Despite the small turning moment of the hair spring, it does affect the operation of the sensing element. This effect does not remain constant, since with the degree of winding (or unwinding) of the spring its torque changes and thus alters the threshold of sensitivity of the instrument over the entire range of its operation.

The elastic system shown in Fig. 2 is free of the above defect. The geared sector is attached to a bent spring 1 whose end is fixed by means of a nonstretching flexible cord 2 to roller 3 which has an effective radius equal to the pitch circle of the driving gear 4.

The flexible cord is fixed in such a manner that the spring tension remains constant over the entire movement of the gear and the roller.

The torque provided by the spring should be larger than that due to the friction force.

A DYNAMOMETER FOR MEASURING TORQUE IN MILLING MACHINES

A. M. Rozenberg, G. L. Kufarev and Yu. A. Rozenberg

Translated from Ismeritel'naya Tekhnika, No. 8, pp. 13-15, August 1960

One of the basic measuring instruments for studying the dynamics of milling metals is the dynamometer for measuring torque. The design of this dynamometer must meet the following requirements: the dynamometer must be rigid in order to eliminate possible vibrations; it must have a small inertia in order to be able to measure instantaneous variations in the cutting force and must be sufficiently sensitive. Moveover the construction of the dynamometer must exclude the effect of other components of the cutting force on the measured torque and must avoid internal losses in the dynamometer.

The Tomsk Polytechnical Institute has developed, taking into account all these requirements, a rigid electrical dynamometer for measuring torque in end and cylindrical milling.

The rigid dynamometer (Fig. 1) consists of a solid body 1 comprising two disks connected to each other by means of 20 radial ribs 2, whose thickness and number determine the stiffness of the system. Experimentally a stiffness was selected to provide a relative displacement of the disks at the place of contact of 10 μ under the effect of a torque of the order to 25 kg-wt · m.

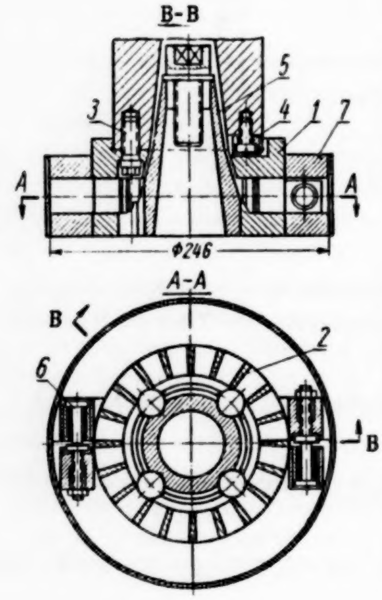


Fig. 1.

The upper disk is fixed to the shaft of the lathe by means of four bolts 3,and the required centering is rendered possible by the cylindrical cavity in the body of the dynamometer. The torque is transmitted from the shaft to the upper disk of the dynamometer by means of two blocks 4 which are secured to the shaft by screws fitting into the appropriate slots in the dynamometer.

The lower disk of the dynamometer has a cone 5 inserted into it in a hot state and welded to it for mounting the conical stem of the cutting tool. The cutting tool is fixed to the body of the dynamometer by means of a screw instead of the usual ram. The torque is transmitted from the lower disk of the dynamometer to the cutting tool by means of two pins on the tool stem, which fit into holes made in the lower disk.

For measuring twist deformations inductive transducers 6 are used, since they have the following advantages as compared with other types: they are simple to manufacture and use, they do not require a complicated amplifying equipment, they are sufficiently sensitive and have a long life since they have no moving contacts or fragile elements.

The transducers are made in the shape of a bobbin fitted into a core made of armco iron. The bobbins are wound with 2400-2500 turns of 0.15 mm. enameled wire. The bobbins are screwed into a casing which is fitted to the dynamometer. The value of the initial gap between the core of the bobbin and the armature is set at 0.1 - 0.15 mm; this gap provides maximum sensitivity for the transducer.

For the mounting of transducers rings 7 are hot pressed onto the lower and upper parts of the dynamometer; one of the rings carries the body (the bobbin with the core) of the first transducer and the stop (armature) of the second transducer, and the other ring carries the armature of the first and the body of the second transducer. These details are mounted in such a manner that on twisting of the dynamometer the gap between the core and armature of one transducer increases while that of the other decreases. The gaps are controlled by rotating the armature. Once established,the gap is set by means of a lock nut.

The inductive transducers are connected to a differential electrical circuit which is more sensitive than a bridge circuit for equal currents in the transducers. Moreover this circuit is simpler and uses less power.

The differential circuit consists of (Fig. 2) two similar closed loops, each of which includes its own transducer T_1 and T_2 and has its own emf. The measuring device is connected to the common part of the two cir-

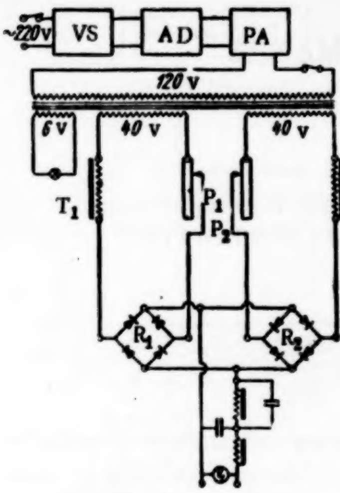


Fig. 2.

cuits and indicates the difference of the currents in the circuits. Before operation equal gaps are set in both the transducers and both circuits are finally balanced by means of wire wound potentiometers P_1 and P_2 (R = 100 ohms), the difference between the currents is then equal to zero. In operation one of the gaps increases while the other decreases, the balance is disturbed and the measuring device registers a current. The unbalance current increases with the variations in the gaps and hence with a rising torque. In order to be able to use the most sensitive and precise instruments of the moving coil type, the alternating current at the output of either circuit is converted into dc by means of semiconductor rectifiers R_1 and R_2 consisting of two bridge circuits. Germanium diodes DGTs-21 or DGTs-22 are used as rectifiers. The current at the output of the circuit is measured visually by means of a microammeter or recorded on a loop oscilloscope.

For recording mean cutting force values the circuit is fed directly from the mains through a voltage stabilizer VS and an autotransformer, and for recording instantaneous values the circuit is connected to a special unit consisting of an audio frequency oscillator AO and a power amplifier PA which provide a 500 cps supply with a highly stable voltage and frequency.

In order to eliminate the carrier frequency in the measuring circuit, T-type filters are used whose parameters are selected to pass without distortion transient process frequencies up to 100 cps and cut off completely the 500 cps. In order to be able to use accurately the same microammeter for measuring large and small values of torque, the instrument's full scale reading is calibrated for medium values of Tq and for large values a multiplying resistor is used.

The tests carried out on the dynamometer showed a complete absence of vibrations, and stability of readings. The calibration of the instrument showed a good linear relation between the value of the torque and the readings of the microammeter. At the same time a high sensitivity was attained which provided readings with an accuracy of 0.1 kg-wt·m with a multiplier resistance, and of 0.3 kg-wt·m with the resistor. Tests have also shown that an axial force of 500 kg-wt and a radial one of 500 kg-wt have no effect on the operation of the instrument. Another advantage of this dynamometer is its simplicity of manufacture, the absence of internal losses and its universal nature which makes its use possible with vertical and horizontal milling machines of various types.

A RATIONAL CHOICE OF PARAMETER RELATIONS IN DIFFERENTIATING DEVICES WITH A RELUCTANT MEASURING INSTRUMENT

L. G. Sobolev

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 15-18, August, 1960

Differentiating measuring devices, which provide a signal representing the derivative with respect to time of the measured parameter, are widely used in various control systems. The problem of providing an accurate and rapid measurement of the derivative of a parameter without unduly complicating the differentiating device involves considerable difficulties, which increase if the measured parameter has an appreciable inertia.

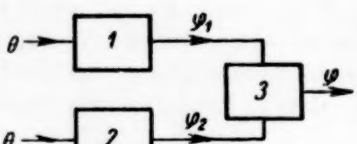


Fig. 1.

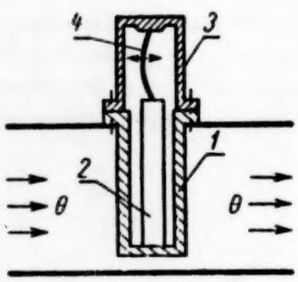


Fig. 2.

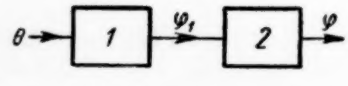


Fig. 3. 1) reluctant thermo - couple; 2) electrical network.

Let us examine the possibilities of raising the accuracy of differentiating devices by a rational choice of parameters for a stable state and by decreasing the dynamic error of transient processes. We shall examine this problem on the example of obtaining a derivative of temperature with respect to time, although all the conclusions remain applicable to derivatives of any parameters measured by means of an instrument possessing inertia.

The transfer function of a single-capacity reluctant element can be represented in the form

$$(T_1 p+1)\varphi_1=k_1\Theta, \tag{1}$$

where T_1 is the thermal element inertia constant which has the dimensions of time; φ_1 - the output signal of the thermal element; Θ - the temperature; k_1 the amplification factor (transfer constant); t - time; p = d/dt.

Modern devices used for measuring the speed of temperature variations can be divided by the type of their transfer functions into two basic groups.

Group a includes devices which consist of two series opposing thermal elements with similar amplification factors, but different inertia, whose transfer function has the form:

$$T_1 T_2 p^2\varphi+(T_1+T_2)\,p\varphi+\varphi=k_1\,(T_2-T_1)\,p\Theta. \tag{2}$$

This group includes the well-known high-speed thermocouple whose schematic is shown in Fig. 1. The temperature is measured by two elements 1 and 2 which have different inertia but the same amplification factor. The output signals φ_1, φ_2 of the elements are fed to the algebraic summator 3 where their difference φ is obtained.

Devices of the type of the high-speed thermocouple are described mathematically by the system of equations

$$\begin{aligned}&(T_1 p+1)\varphi_1=k_1\Theta;\\&(T_2 p+1)\varphi_2=k_1\Theta;\\&\varphi=\varphi_1-\varphi_2.\end{aligned} \tag{3}$$

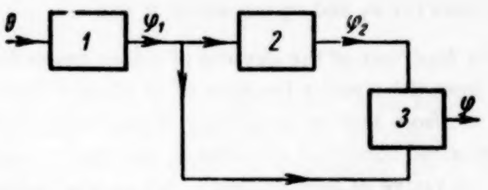


Fig. 4. 1) thermal element; 2) aperiodic link 3) summator.

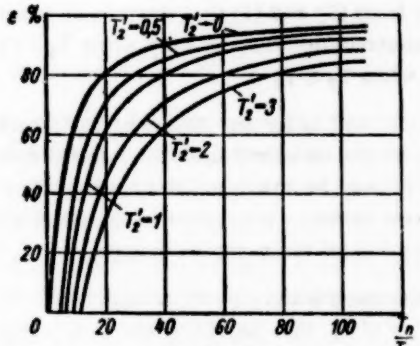


Fig. 5

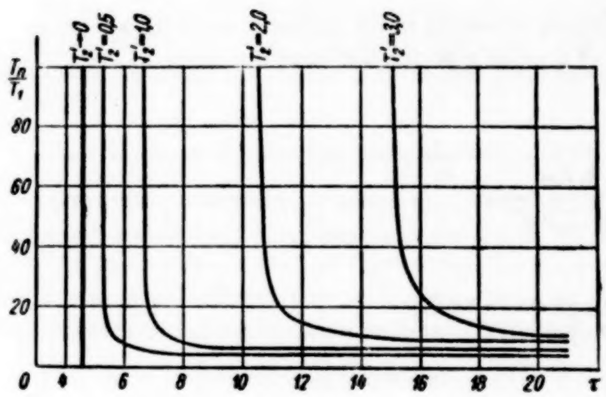


Fig. 6

By substituting in (3) φ_1 and φ_2 we obtain (2).

The high-speed thermocouple is not the only possible element of group a. Let us now examine the schematic of Makhan'kov's dilatometer [1] shown in Fig. 2.

The dilatometer consists of an external tube 1, an internal rod 2, frame 3, connected to tube 1, and a flexible plate 4 which is fixed between rod 2 and frame 3. The rod and the external tube are made of the same material. The output signal of the dilatometer, consisting of the bending of the middle portion of plate 4, is proportional to the difference between the expansion of the rod and the tube.

It can easily be seen that this instrument is a differentiating device of group a. In fact, the external tube and the internal rod serve as thermal elements which have similar amplification factors (the same material) but different inertia (different masses and conditions of heat transfer). The output signals of these thermal elements (linear displacements) are subtracted by means of a simple kinematic arrangement which serves as an algebraic summator. The operation of the elements of such a regulator and their mathematical recording are represented by the system of equations given in (3).

The differentiating devices of the b group have a transfer function of the form:

$$T_1 T_2 p^2 \varphi + (T_1 + T_2) p\varphi + \varphi = k_2 T_2 p \theta. \qquad (4)$$

Let us examine a differentiating device which consists of a series connected reluctant thermocouple with a transfer function represented by (1) and an RC network whose equation in this case can be written as

$$(T_2 p + 1)\varphi = T_2 p \varphi_1. \qquad (5)$$

The schematic of this device is shown in Fig. 3. The device is represented by a system of equations:

$$\begin{aligned} (T_1 p + 1)\varphi_1 &= k_2 \theta; \\ (T_2 p + 1)\varphi &= T_2 p \varphi_1. \end{aligned} \qquad (6)$$

By excluding from (6) φ_1 we obtain (4).

It is also possible to have a differentiating device consisting of a reluctant thermocouple, aperiodic link and a summator as shown in Fig. 4.

This device is represented by a system of equations:

$$\begin{aligned} (T_1 p + 1)\varphi_1 &= k_2 \theta; \\ (T_2 p + 1)\varphi_2 &= -\varphi_1; \\ \varphi &= \varphi_1 + \varphi_2. \end{aligned} \qquad (7)$$

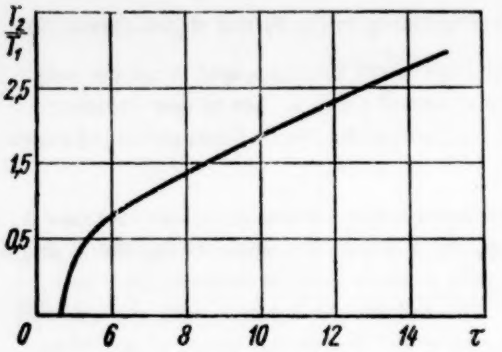


Fig. 7

Excluding from (7) φ_1 and φ_2 we arrive at (4).

The transfer functions of the devices of either group differ considerably from the transfer function of an ideal differentiating device (i.e., from such an imaginary device which both in a static and dynamic condition provides an undistorted measurement of the derivative of temperature). Let us now compare the devices of groups a and b and an ideal differentiating device for various laws of temperature variations. In analyzing, let us examine both the transient and the state conditions.

It will be seen from (2) and (4) that devices of group a can operate in a predetermined manner only when $T_2 > T_1$ and those of the b group when $T_2 \gtrless T_1$

The comparison of (2) and (4) shows that it is possible to select k_1 and k_2 for any values of T_2 in such a manner that the right hand sides of (2) and (4) are equal. However, in this transformation the coefficients of the first and second derivatives of φ in the left hand sides of (2) and (4) can be made smaller for the b than the a group devices, hence the b group devices can be made nearer in their dynamic properties to the ideal differentiator than group a devices. This qualitative conclusion holds for any law of temperature change.

In order to establish the quantitative relations let us examine the most widely used harmonic law for measuring temperature. It is then advisable to introduce relative time $\tau = t/T_1$, thus providing the possibility without reducing the generality of the conclusions to decrease the number of independent parameters and use the advantages of a relative form of expressing the variables.

With the above notations and the temperature changing according to the harmonic law with a relative period of $T'_n = T_n/T_1$, the equation for an excited state of a group a device will have the form:

$$\varphi = \frac{k_1\omega_1}{1+\omega_1^2} e^{-\tau} - \frac{k_1 T_2' \omega_1}{1+(T_2')^2\omega_1^2} e^{-\frac{\tau}{T_2'}} + \tag{9}$$

$$+ \frac{k_1 (T_2' - 1)\,\omega_1}{\sqrt{(1+\omega_1^2)\,[1+(T_2')^2\omega_1^2]}} \sin(\omega_1\tau + \psi),$$

where

$$\omega_1 = \omega T_1 = \frac{2\pi}{T_n / T_1}; \qquad T_2' = \frac{T_2}{T_1};$$

$$\psi = \tan^{-1} \frac{1 - T_2'\omega_1^2}{\omega_1 (1+T_2')} \tag{10}$$

For the same conditions the equation of an ideal differentiator has the form:

$$\varphi = k\omega_1 \sin\left(\omega_1\tau + \frac{\pi}{2}\right). \tag{11}$$

A comparison of (9) and (11) shows that the last term of (9) is similar in form to (11), but differs in principle. The phase shift ψ for an ideal differentiator is always positive and equal to $\pi/2$, and for a real one it is not $\pi/2$ and depends on the parameters of the device in a manner shown by equation (10). The nearer angle ψ is to $\pi/2$ the smaller will be the distortions introduced by the differentiating device.

Let us denote the accuracy of the differentiating device for stable state temperature oscillations by a dimensionless quantity ϵ:

$$\varepsilon = \frac{2\psi}{\pi}. \tag{12}$$

An analysis of (10) shows that in an actual differentiator it is impossible to obtain $\psi = \pi/2$ for any values of T'_2 or ω_1. Hence differentiating devices of either group cannot provide accurate measurements of the speed of temperature variations for a harmonic law of these variations.

It is known that group a devices can only be used at frequencies below the critical [2].

$$\omega_{cr} = \frac{1}{\sqrt{T_1 T_2}}, \tag{13}$$

which corresponds to $\psi = 0$.

Considering that the equation of the excited state of a group b device differs from (9) only by a constant factor, the above limitation should be applied to these devices as well. It should be noted, however, that for a device of the b group both the accuracy of measurement ϵ for $T_2 < T_1$ and a stable state of oscillations and the value of the critical frequency ω_{cr} are always higher than for the a group devices.

Fig. 5 shows the relation of ϵ to T'_n for the different values of T'_2 which provides the accuracy of measurements of the derivative for a stable state of any concrete device.

The first two terms in (9) which do not exist in (11) have as a factor an exponent with a negative index proportional to time, i.e., they characterize the interference which decays at the end of the transient process.

Let us evaluate the dynamic properties of the differentiating devices by the length of the transient process i.e., by the relative time $\tau = t/T_1$ during which the ratio of the signal representing the interference to the signal representing the maximum value of the stable state movement drops to 0.01,and from then on does not exceed that value.

The relation of the transient process duration to T'_n for various values of T'_2 is shown in Fig. 6.

By a similar technique the author of this article has also found the behavior of the group a and b devices with exponential and linear temperatures variations. In these cases the duration of the transient process when $T_2 < T_1$ for group b devices is also smaller than for group a, but on completion of the transient process the devices of both groups differentiate accurately. Thus, for instance, for a linear variation of temperature (with any speed) the duration of the transient process in relation to T'_2 is determined from the curve in Fig. 7.

This curve also determines the duration of the transient process for harmonic and exponential variations of temperature in the limiting case (for large values of T'_p and T'_e).

The analysis of the results thus obtained shows that a reduction in the value of T'_2 always improves in theory the properties of an actual differentiating device However, a reduction of T'_2 below $T'_2 = 0.5$-0.6 is not expedient since it only produces a small effect.

The above data make it possible to arrive at the conclusion that for measuring the speed of temperature variations (as well as any other parameters which can be measured by an electronic device) it is expedient to use group b devices for the ratio of the device parameters equal to $T_2/T_1 \simeq 0.5$-0.6.

Let us also note that group b devices also posses a definite practical advantage. It is easy and simple to select for them the required value of ratio T_2/T_1 by varying T_2 a parameter of the link which is not directly related to temperature measurements (for instance the RC link connected in series with the thermocouple in the group b devices).

In the group a devices the selection of T_1 and T_2 is incomparably more difficult, since it normally requires the variation of the masses of thermal elements. The readjustment of the ratio T_2/T_1 during the operation of group a devices is in practice impossible.

LITERATURE CITED

1. G. N. Makhan'kov, Élektricheskii Stantsii, 6 (1957)
2. Yu. I. Sitnitskii, Teploénergetika, 9 (1958)

ELECTRICAL MEASUREMENTS

APPLICATION OF THE DIFFERENTIAL CALORIMETER IN MAGNETIC MEASUREMENTS

V. P. Karpenko

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 19-23, August, 1960

In recent years several scientists have attempted to use calorimeters for magnetic measurements (Spooner, 1927; Hund, 1931; Greig and Keiser, 1948). However, calorimeters were never extensively used for these measurements, and this question was never discussed sufficiently in literature.

Below we give the results of a study carried out by us on the possibility and expediency of using differential calorimeters for measuring losses in ferromagnetic materials.

In calorimetric measurements the electrical energy is converted into heat by hysteresis, eddy currents and their effects in the sample ferromagnetic material under test. These losses of electrical energy correspond to the heat produced in heating up the liquid into which the sample is immersed.

The system in which the liquid is heated must not have any leakage either of thermal or electrical energy (radiation, etc.).

Since in industrial conditions the losses in the cores normally used in high frequency equipment only amount to a few watts or fractions of a watt, the calorimeters must be highly sensitive.

The differential calorimeter system which provides comparisons of the measured power with a known one are very sensitive and accurate in measuring small powers. This effect is attained by the fact that the heat exchange, radiation and other losses of the two calorimeters cancel each other and do not affect the measurement results. But this only holds if the two systems are identical.

Hund's differential calorimeter is the most convenient to use (Fig. 1), since it makes it possible to exclude the copper losses in the magnetizing winding from the measurement results.

The defect of this system consists in the unequal thermal capacity of the two calorimeters which leads to errors of measurement.

Let us examine the general equation for the heat balance of a calorimetric system.

The condition for a heat balance of the system is:

$$Q\,dt = \sum m_i c_i\, d\vartheta + \alpha S(\vartheta_n - \theta)\, dt \tag{1}$$

where Q is the thermal.power; Qdt - the amount of heat dissipated in the system in time dt; $\Sigma m_i c_i$ - the total thermal capacity of the oil samples, copper windings, thermocouples, contacts and containers; S - cooling surface of the system; α - the heat transfer coefficient of the system; ϑ_n - temperature of the systems at instant $\underline{t}$; θ - the ambient termperature.

The general solution of this equation for determining the variation in the calorimeter excess temperature over the ambient medium is expressed by the equality;

$$\vartheta = \vartheta_{st}\left(1 - e^{-\frac{t}{T}}\right), \tag{2}$$

where

$$\vartheta = \vartheta_n - \theta.$$

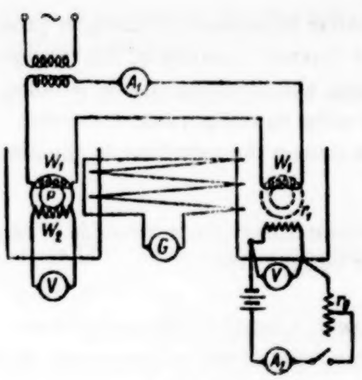


Fig. 1.

The temperature of the stable state condition is

$$\vartheta_{st} = \frac{Q}{\alpha S}. \tag{3}$$

The calorimeter time constant is

$$T = \frac{\Sigma m_i c_i}{\alpha S}. \tag{4}$$

If term $e^{-t/T}$ in (2) is expanded into a Maclaurin's series we shall have:

$$\vartheta = \frac{Q}{\alpha S}\left(\frac{t}{T} - \frac{t^2}{2T^2} + \frac{t^3}{6T^3} - \ldots\right). \tag{5}$$

If we then assume that the measurement is made in the initial period (when $t \ll T$) it is possible to neglect all the terms except the first in equation (5) and write:

$$\vartheta = \frac{Q}{\Sigma m_i c_i}\, t. \tag{5a}$$

i.e., the measured temperature difference in the transient period is proportional to the amount of heat supplied, inversely proportional to the thermal capacity of the system and does not depend on the heat exchange coefficient α.

The assumption made in [1], that if the calorimeter is used in its initial period only it is possible to consider that $t \ll T$, only holds if the time spent on measuring is considerably smaller than the calorimeter time constant, which is only feasible with large calorimeters when measuring large powers. When small losses are measured in ferrites, for which the use of differential calorimeters is especially suitable owing to the calorimeters' high sensitivity and the possibility of excluding copper wire losses, it is no longer possible to neglect the second term in (5). Moreover, it is not possible in a transient state to neglect the time taken by the galvanometer readings in the thermocouple battery circuit and the possible inequality of the thermal capacity of the two systems. Hence, when measuring small powers by a differential calorimeter the errors in the transient state will be much greater than those in a steady state.

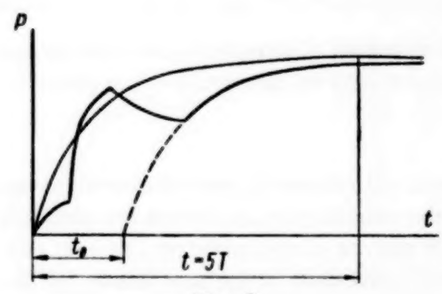


Fig. 2

It should be noted that the time saved by measuring in the transient condition is small, since after placing the sample in the calorimeter it is necessary to spend about the same amount of time for setting the temperature of the system before measurements in the transient as in the stable state condition.

The thermal exchange coefficients of the system are in general indeterminate and greatly affected by the temperature and the cooling conditions of the system. But in the particular case of measuring small stable state temperatures (a few degrees or fraction of a degree) this coefficient can be considered to be stable, since measurements are made in a limited closed space where the loss of heat by convection and radiation can be neglected. Under these conditions the complex process of heat exchange can be considered as a simple phenomenon of heat conduction. The insulating of the calorimeter is usually made to reduce the heat dissipation into the surrounding space to a minimum. Thus the heat transfer coefficient can be considered independent of the stable state temperature. Hence, a sufficiently high accuracy can be achieved in the stable state condition of measurements.

Measurement technique. The calorimeters are calibrated before measurements. For this purpose polystyrene toroidal sample substitutes with manganin wire heaters on their side surfaces are used. By impressing on these windings dc powers of equal values the system is calibrated and their equality is checked. If the systems are identical and the sample substitutes are placed symmetrically, the two heating curves should coincide.

During measurements both systems are loaded in addition with two similar ferromagnetic samples (also of a toroidal shape) one of which is tested and the other serves to balance the thermal capacity of the two systems. It is very important to have the lead-out wires of thermocouple, heaters, and the magnetizing winding of a small cross section in order to reduce heat conduction through them. In order to compensate the copper losses, a magnetizing winding is wound on the sample in one of the containers and on the substitute in the other container.

Depending on the accuracy required and the permissible duration of measurements, three methods of testing losses in ferromagnetic samples by means of differential calorimeters can be specified.

1. In a stable state with full balancing (i.e., when the balancing dc power is equal to the losses in the sample) and the direct current in the heating winding adjusted to make the deviation of the galvanometer in the thermocouple battery circuit equal to zero.

In this instance the measured power is determined from the formula

$$P_{ms} = P_{dc} \tag{6}$$

This is the most accurate method but it takes a longer time to carry out. The dc power P_{dc} can be calculated from the last value of the current obtained in adjusting the circuit. It will be seen from Fig. 2, however, that the duration of the measurement must be increased according to the time it takes to obtain a steady adjustment of the dc current.

It is also possible to make a second measurement after having obtained the required value of the dc current and having allowed the system to cool. This will raise a little the accuracy of measurement, (as it will be explained later) but the duration of testing will increase still further.

2. In a steady state of the system, with incomplete balancing, and using the reading obtained on the galvanometer in the thermocouple battery circuit. The measured power will then be equal to:

$$P_{ms} = P_{dc} + k_s a_{ms} \tag{7}$$

where $k_s = P_1/a_s$ is the steady state calorimeter calibration constant; a_{ms} - the galvanometer reading during the measurement.

3. When measuring in a transient state the measured power can be expressed by the formula

$$P_{ms} = P_{dc} \pm k_1 a_{ms} \tag{8}$$

where $k_1 = P_1/a_1$ is the transient state calorimeter calibration constant at instant t_1 when the galvanometer reading a_{ms} is taken. (For equal time constants of both systems, k_1 will depend only on the instant t_1 the galvanometer reading is taken).

Analysis of the errors of measurement. The use of the differential calorimeter system eliminates several important defects and errors characteristic of a single calorimeter. If the calorimetric containers are identical it is possible to eliminate the error due to heat radiation by the external surface of the containers, to heat conduction by the system elements which contact air, to the conduction and convection of the heat insulating layer of air, to the inequality of the thermocouple characteristics, etc.

However, certain factors which affect the accuracy of measurement remain in the circuit.

In evaluating the measurement error it is first of all necessary to consider the formula used for determining the measured power.

1. In the steady state condition, with full balancing, when the measured power is determined from (6), the error will be equal to that of the measured dc power:

$$\varepsilon_{P_{ms}} = \varepsilon_{P_{dc}}\,. \tag{9}$$

i. e., it depends on the method of measuring dc power and on the method adopted for connecting the instruments and the elements.

It is known that the dc power can be calculated from one of the formulas:

$$P_{dc} = UI; \quad P_{dc} = I^2 r_H; \quad P_{dc} = \frac{U^2}{r_H}, \tag{9a}$$

where U is the voltage across the terminals of the heater; I - the current in the heater circuit; r_H - the resistance of the heater.

Considering that the readings on the voltmeter or ammeter are taken in the range of 40-100% of the scale the maximum possible error of the instrument amounts to

$$\varepsilon_U = \varepsilon_I \simeq (3-1)\, K\%, \tag{9b}$$

where K is the grade of the instrument.

The error due to the power consumed by the instruments is of a systematic nature and can be accounted for by appropriate corrections (for a voltmeter $c = U^2/r_v$, for an ammeter $c = I^2/r_a$).

Since in the above case small powers are being measured, it is desirable to use instruments with a smallest possible power consumption in order to avoid inaccuracies in determining the corrections.

Errors in determining dc power by the formulas given above can be respectively taken as:

$$\varepsilon_{P_{dc}} = \pm 2\,(3-1)\, K\%. \tag{10}$$

or

$$\varepsilon_{P_{dc}} = \pm\, [2\,(3-1)\, K + \varepsilon_{r_H}]\, \%. \tag{11}$$

If instruments of the 0.2 grade are used the error in measuring the resistance will be ± 0.1% and the error calculated from (11) will be (1.3 - 0.5) %.

On an average it is possible to take that $\varepsilon_{P_{dc}} \simeq \pm 1.0\%$.

It will be seen from Fig. 2 that the time t_0 required for the direct current stabilization produces an additional error which can be determined in the following manner.

The heating curves of both systems are determined by the following equations:

$$\begin{aligned} p_1 &= P_{n1}\,(1 - e^{-\frac{t}{T}}), \\ p_2 &= P_{n2}\,(1 - e^{-\frac{t+t_0}{T}}), \end{aligned} \tag{12}$$

where p_1 and p_2 are powers in the calorimeters at instant $\underline{t}$; P_{n1} and P_{n2} are powers corresponding to $t = \infty$. If the two systems have equal dc powers applied to them the difference in the ordinates of these curves at the instant measurement will amount to:

$$\Delta p = P_n e^{-\frac{t}{T}} (e^{-\frac{t_0}{T}} - 1). \tag{13}$$

This difference represents the absolute error in measuring power losses in the sample. Its value increases with a rising time t_0 for the stabilization of the direct current, it will be maximum when $t_0 \to \infty$ and will equal to:

$$\Delta p = P_n e^{-\frac{t}{T}}. \tag{14}$$

If we assume that measurements are made during time $t = 5T$, then $\Delta p = P_n \cdot 0.006$.

The relative maximum error is

$$\xi_P = \frac{\Delta p}{P_n} \cdot 100 = e^{-\frac{t}{T}} \cdot 100\%. \tag{15}$$

This error is of a systematic nature and can be accounted for by means of calibration tables relating it to the time required in stabilizing the direct current.

It has already been stated that this error is eliminated if the measurement is repeated.

In addition to the above errors it is also necessary to consider others due to various secondary factors; such as insufficient sensitivity of the system, effects of stray emfs in the thermocouple circuit, effect of additional frequency dependent losses in the calorimeter (frequency errors), differences in the properties of the calorimetric containers.

Let us examine these errors in greater detail.

Errors due to an insufficient sensitivity of the device for measuring a given power are determined by the equation:

$$\xi_{P_s} = \pm \frac{\Delta P_s}{P_n} \cdot 100\%. \tag{16}$$

These errors depend on the number of thermocouples, their sensitivity, and on the sensitivity of the indicating instrument in the thermocouple circuit. These errors rise with a decreasing measuring temperature.

The value of ΔP_s can be determined from the equality

$$\Delta P_s = \frac{\Sigma\, mc\, \Delta\theta}{0{,}24\, t}, \tag{17}$$

where Σ mc is the total thermal capacity of the system.

The minimum temperature deviation which can be seen on the galvanometer deflection in the thermocouple circuit is

$$\Delta\theta = \frac{E}{U_T}, \tag{18}$$

where $E = c_1 a_1 r_{TG}$ is the minimum thermocouple emf which can be read on the galvanometer; r_{TG} - the resistance of the galvanometer and thermocouple circuits; c_1 - the galvanometer constant; a_1 - the minimum deflection of the galvanometer; U_T - the thermopile emf for a temperature variation of 1°C.

By substituting these values in (17) we obtain:

$$\Delta P_s = \frac{\Sigma\, mc c_1 a_1 r_{TG}}{0{,}24 t\, U_T}. \tag{19}$$

The error due to stray thermal emfs is caused by the soldered and pressed joints of various metals being at different temperatures. In order to avoid stray thermal emfs in the auxiliary joints of the differential thermopile, both its lead-out wires should be made of copper. At the places where the copper wires are joined to the brass terminals the thermal emfs for temperature difference of 1-5°C will be very small and can be neglected.

Frequency errors can be caused by losses produced in various parts of the calorimeter by the high frequency current which is flowing in the magnetizing winding.

In determining the frequency losses of the device only the losses in the sample substitute need be taken into account, since the losses in the copper windings and the surrounding objects are the same in both systems and balance out in measurements.

This assumption was checked experimentally. The losses in the polystyrene sample differ very little from those in air and the frequency errors in this case can be neglected.

Errors due to the difference in the calorimetric containers are caused by asymmetrical heat exchange and variations of temperature in the laboratory premises.

Errors due to the asymmetry of heat exchange are normally caused by the inequality of the thermal conductivity coefficients of the two systems. This inequality produces different distributions of the two systems' temperature fields caused by the difference in the effects of the surrounding media. These errors cannot be determined theoretically, only certain relations can be obtained experimentally.

Errors due to the asymmetrical heat exchange are greatly influenced by the construction and careful manufacture of the instrument. When equal dc powers are applied to the two systems the galvanometer in the thermocouple circuit should remain on zero. Any deflection of the galvanometer in a stable state condition shows an unequal heat exchange in the systems or a non uniform distribution of temperature fields. Both the first and the second phenomenon are eliminated by making the systems as symmetrical as possible until a zero deflection of the galvanometer is obtained.

Temperature variations in the laboratory premises affect measurement results only if the two systems have unequal thermal conductivity coefficients. If the latter are equal this error is eliminated.

In order to determine approximately the numerical value of the total error of a calorimeter let us assume that the thermocouple circuit is connected to a galvanometer type G3S with a calibration of $c_1 = 8.5 \cdot 10^{-10}$ amp/division; the minimum noticeable deflection $a_1 = 0.3$ div.; the thermometer circuit resistance $r_{TG} = 640$ ohms; the time constant of the device T=30 min.; the emf of the thermopile per 1°C $U_T = 0.8 \cdot 10^{-3}$v; the total thermal capacity of the system Σ mc = 4.5 w·sec/°C. By substituting these values in (16) and (19) we find that the error due to the lack of sensitivity in the calorimeter when measuring a power $P_{ms} > 0.005$ w is equal to ± 0.14% and the total error with (11) taken into account is equal to ± 1.14%.

2. With incomplete balancing of the system in a stable state condition and when calculating the measured power from (7) the total error is determined by the equation:

$$\xi_{P_{ms}} = \pm \frac{P_n \xi_{P_n} + k_y a_{ms}(\xi_{k_{st}} + \xi_{a_{ms}})}{P_{ms}} \tag{20}$$

The error in determining the power is calculated from (10) and (11).

The error in determining the permanent calibration of the calorimeter consists of two errors:

$$\xi_{k_{st}} = \xi_{p_1} + \xi_{a_{st}} \tag{21}$$

where ξ_{p1} is determined from (10) and (11) and the error of the galvanometer reading is

$$\xi_{a_{st}} = \pm \frac{\Delta a_{st}}{a_{st}} \cdot 100\,\%. \tag{22}$$

By limiting the lower reading limit of the galvanometer by $a_{st} = 30$ div. it is possible to consider that the reading error does not exceed ± 1.0%. Then the error in determining the permanent calibration will amount to ± 2.0% . Additional errors will in this case remain the same as in the case of a stable state condition.

By inserting the appropriate value in (20) and considering that the measured power is approximately equal to 5 mw, and the value of the balancing power equals about 80% of the measured power, we shall obtain a numerical value for the total error:

$$\xi_{P_{ms}} = \pm 0.14 + \frac{4 \cdot 10^{-3} \cdot 0.01 + 1 \cdot 10^{-3}(0.02 + 0.01)}{5 \cdot 10^{-3}} \cdot 100 \simeq 1.5\,\%. \tag{22a}$$

3. When measuring in a transient condition and determining the measured power from (8) the measurement error is determined from a similar formula:

$$\xi_{P_{\mathrm{ms}}} = \pm \frac{P_n \xi_{P_n} + k_1 a_{\mathrm{ms}} (\xi_{k_1} + \xi_{a_{\mathrm{ms}}})}{P_{\mathrm{ms}}} \cdot 100\,\%. \tag{23}$$

In addition to the above errors in the transient condition the errors due to unequal thermal capacity of the systems, the time taken in obtaining a reading and a stable galvanometer deflection are also important.

When the calorimeter is carefully manufactured and the two systems are specially balanced the error due to the above reasons can be reduced to not more than ± 0.3%. This error was checked experimentally.

If a galvanometer G3S, with a specially increased lagging, is used in the thermocouple circuit, the stabilization time of readings may amount to several seconds. In the initial stage of heating the temperature in the containers rises very rapidly, and is liable to change considerably during the time taken by the reading of the galvanometer.

Considering that the measurement lag is $\Delta t = 10$ sec and that the galvanometer reading is taken 15 min after the current has been switched on, the error due to the lag in reading will be of the order of $\xi_s = \pm 1\%$ (if the instrument time constant is $T = 30$ min). This error rises with a decreasing time constant of the device.

Thus the approximate numerical value of the total calorimeter error in the transient condition when the above relations and (20) are taken into account together with the additional errors due to unequal thermal capacity and to the lag in taking galvanometer readings will amount to:

$$\xi_{P_{\mathrm{ms}}} = \pm \frac{4 \cdot 10^{-3} \cdot 0.01 + 1 \cdot 10^{-3}\,(0.02 + 0.01)}{5 \cdot 10^{-3}} \cdot 100 + \\ + 1.0 + 0.14 + 0.1 \simeq 3.0\,\%. \tag{23a}$$

Conclusions. The calorimetric method of measuring losses in ferromagnetic materials can be used as a control method for checking the accuracy of measuring devices and for checking magnetic characteristics of materials at high frequencies under laboratory conditions (at plants producing magnetic materials) and in research institutes. This method is the most reliable when the voltage or current waveform are distorted, since the measurement results are almost completely independent of frequency.

The differential calorimetric system provides measurements of small losses in ferromagnetic materials at high frequencies with great precision. Measurements of a power greater than 5 mw in a stable state condition and a completely balanced system can be made with an accuracy of the order of ± 1%. The sensitivity at the same time can be sufficiently high (the threshold of sensitivity in our case amounts to approximately 0.005 mv).

LITERATURE CITED

1. K. B. Karandeev, Application of Differential Calorimeters in Electrical Measurements [in Ukrainian] (L'vov Polytechnic Institute, Scientific papers, 1947).

METHODS AND DEVICES FOR AN ACCURATE INDICATION OF A 90° PHASE SHIFT

P. P. Ornat-skii, Yu. A. Skripnik and N. F. Suvid

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 24-29, August, 1960

In various circuits such as those used for checking wattmeters, for rectangular coordinate balancing devices, ac unbalanced bridges, for checking the phase error in mutual inductances, etc., devices for an accurate reading of a 90° phase difference are required. Requirements for the selectivity, precision, frequency range and immunity from outside interference of 90° phase difference indicators are constantly rising, especially in connection with the production of grade 0.1 wattmeters, small power factor measuring wattmeters, high frequency balancing devices, reference mutual inductances for a wide frequency range, etc.

In connection with the extended range of application and stricter requirements for the 90° phase difference indicators it is expedient to examine various types of their circuits in order to find their properties and areas of application.

Devices for indicating 90° phase differences can be divided into the following groups.

<ins>Compensation phase indicators</ins> which have a 90° phase difference standard and whose balance indicator's deflection angle is proportional to the angular error in the 90° phase shift.

Reference mutual inductances are usually used as standards in these indicators. A schematic for measuring a 90° phase difference between two currents I and I_1 is shown in Fig. 1.

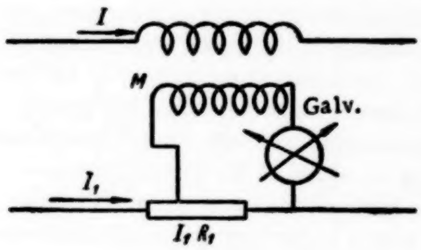


Fig. 1.

If the angular error in mutual inductance M and the reactance of resistance R_1 are equal to zero, the circuit can only be balanced if the phase difference between I and I_1 is 90°.

If the angle between I and I_1 is $90° \pm \delta$, it is impossible to balance the circuit and the deflection of the balance indicator becomes:

$$\alpha = \pm k\omega IM\delta. \tag{1}$$

The angular error of the 90° phase difference indicator which is determined by the threshold of sensitivity is equal to:

$$\delta_1 = \tan^{-1}\frac{2A}{E_2}, \tag{2}$$

where A is a constant of the voltage balance indicator; E_2 - the emf at the terminals of the secondary winding of the reference mutual inductance.

When a galvanometer type M501 is used for indicating the balance, angle δ is equal to 8.52" for E_2 = 1 v.

When checking small power factor measuring wattmeters of the 0.5 grade, it is necessary to make the angular error, only due to the insufficiently accurate setting of the 90° phase difference, not greater than 0.1%. Hence, the angular error of the 90° phase difference which is equal to:

$$\gamma = \frac{\sin\delta}{\cos\varphi_{\text{nom}}} 100\% \simeq \frac{\delta}{0.1} 100\%, \tag{3}$$

should not exceed

$$\delta = \frac{0.1 \cdot 0.1}{100} 3438 = 0.34' \simeq 20''. \tag{4}$$

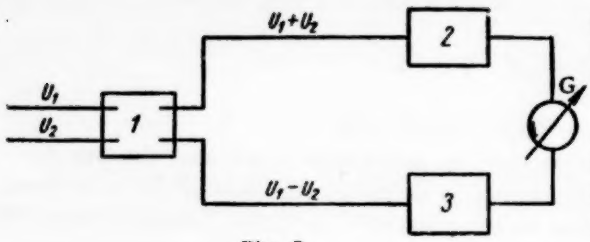


Fig. 2.

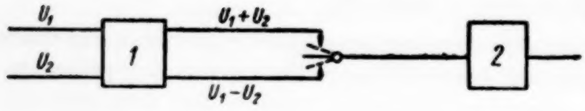


Fig. 3.

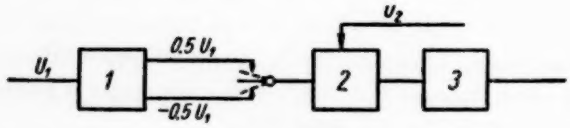


Fig. 4.

However, the mutual inductance M has a finite angular error δ_2 and resistance R_1 possesses a reactance which produces an angular error of $\delta_3 = \omega\tau$, where τ is the time constant of resistance R_1.

Thus the error in the indication of the 90° phase difference is determined not only be the threshold of sensitivity, but also by angular errors of the mutual inductance and the reactance of the resistor.

The angular reading errors δ_2 and δ_3 rise with a rising frequency and at 1000 cps become approximately equal to $\delta_2 \simeq 20''$ (for a reference coil of the Sullivan Co) and $\delta_3 \simeq 24''$ (for a reference resistance with a time constant of $\tau = 2 \cdot 10^{-8}$ sec).

The difficulties of indicating a 90° phase difference by means of a reference coil increase with a rising frequency not only due to the rise in the angular error, but also due to the instability of the supply sources used at higher frequencies. Variations in the frequency and voltage of the supply sources make the output voltage U_1 and U_2 of the compensation indicator change continuously. Thus,balancing by means of the compensation circuit becomes very difficult. Since at the present time the production of highly stable high frequency oscillators has been achieved on the whole, the extension of the frequency range of compensation phase indicators depends on the development of reference mutual inductance coils for a wide frequency range (with a permissible angular angular error). If stable supplies are lacking, it is necessary to make the 90° phase difference indicating devices less sensitive to the input frequency and voltage oscillations.

Electromechanical phase indicators ,whose indicator deflection or oscillation angle is proportional to the angular error of the 90° phase difference.

Any electrodynamic or ferrodynamic instrument with two separate circuits can be used as an electromechanical phase indicator. If there is a 90° phase difference between the measured currents and voltages the torque in such instruments is equal to zero. Electrodynamic instruments with a light beam amplification can have a sensitivity of $S_\delta = 0.5$ div./1" for measuring currents of 10 ma.

The defects of the electromechanical phase indicators consist of their sensitivity to the presence of higher harmonics in the measured currents (voltages) and their inherent angular error. Hence,electromechanical phase indicators can be successfully used mainly in circuits with a fixed frequency and with one of the compared voltages (currents) having a sinosoidal waveform.

The use of highly sensitive phase indicators in low frequency compensating devices made it possible greatly to simplify the measurements by means of separate balancing of the circuit [1].

Devices based on phase-sensitive circuits, whose output variable is proportional to the angular error of the 90° phase difference.

There are many 90° phase difference indicating devices based on phase sensitive elements consisting of vacuum tube or transistor circuits [2-7].

The schematic of any phase-sensitive arrangement can be represented (Fig. 2) by unit 1 for the addition and subtraction of the compared voltage vectors $u_1 = U_1 \sin\omega t$ and $u_2 = U_2 \sin(\omega t + \varphi)$, and a differential rectifier 2 and 3 whose one half is fed by the geometrical sum and the other half by the geometrical difference of the voltages being compared.

Galvanometer G connected to the output of the differential rectifier 2, 3 determines the difference be-

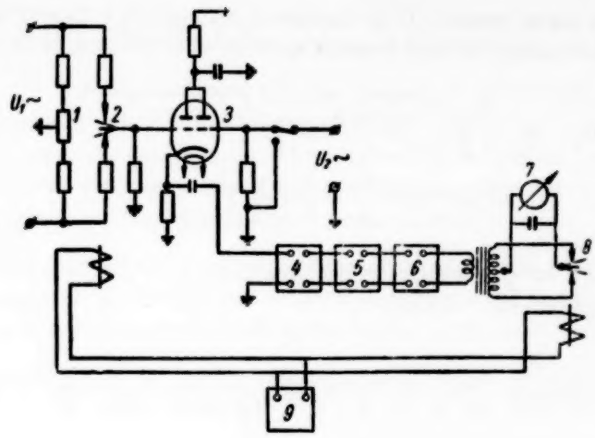


Fig. 5.

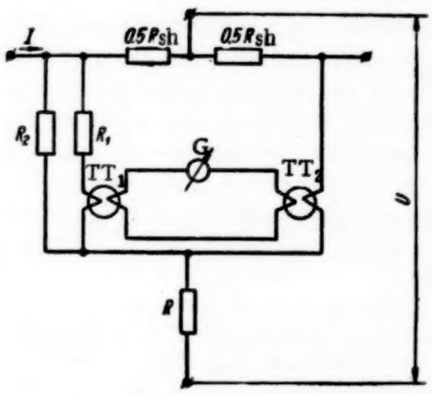


Fig. 6.

tween the voltages being rectified, i. e.,

$$U_G = k_1 \sqrt{U_1^2 + U_2^2 + 2U_1U_2\cos\varphi} - \\ - k_2 \sqrt{U_1^2 + U_2^2 - 2U_1U_2\cos\varphi} \tag{5}$$

where k_1 and k_2 are the transfer constants of the two halves of the differential rectifier.

The zero reading of the galvanometer corresponds accurately to a 90° phase difference between the two compared voltages U_1 and U_2 only if the two halves of the rectifier are identical, i.e., if $k_1 = k_2 = k$.

With the normal dispersion of the characteristics of tubes and transistors, it is almost impossible to compensate the inequality of the two halves over a wide range of frequencies for different levels of the compared voltages. Therefore, the accuracy of reading of such phase indicators does not exceed 0.5 - 1° with a sinusoidal waveform of the voltages under test. In the presence of higher harmonics the accuracy of reading is considerably lower.

The error due to the inequality of the two halves of the differential rectifier can be completely eliminated if the two voltages 1 (the sum and the difference) are fed sequentially to the same rectifier 2 with the duration of the effect of each voltage on the rectifier made considerably larger than the period of oscillations of the voltages being compared.

As the result of this, the rectifier will be fed with a voltage whose amplitude will vary periodically from a maximum to a minimum by the difference between the sum and the difference of the voltages:

$$U_{max} = U_c = U_1 \sin\omega t + U_2 \sin(\omega t + \varphi), \\ U_{min} = U_p = U_1 \sin\omega t - U_2 \sin(\omega t + \varphi). \tag{6}$$

The voltage pulses fed to the rectifier can be considered as an amplitude modulated voltage with the frequency equal to the repetition frequency of the alternate supply of the sum and difference voltages to the detector circuit, i.e., the voltage at the output of the detector can be represented approximately by *

$$U_\omega = U_m (1 + m \sin\Omega t) \sin\omega t. \tag{7}$$

Where $U_m = U_s + U_d / 2$ is the mean value of the "carrier" frequency voltage; $m = U_s - U_d / U_s + U_d$ is the depth of the amplitude modulation; $\Omega = 2\pi f_k$, where f_k is the commutation frequency of the sum and difference voltages; $\omega = 2\pi f$ where f is the frequency of the voltages being compared.

From the modulated oscillations, the detector picks out the low frequency (commutation) oscillations whose voltage is equal to:

$$U_\Omega = kU_m m \sin\Omega t = k\left(\sqrt{U_1^2 + U_2^2 + 2U_1U_2\cos\varphi} - \right. \\ \left. - \sqrt{U_1^2 + U_2^2 - U_1U_2\cos\varphi}\right) \sin\Omega t. \tag{8}$$

* The expressions are derived for a sinusoidal modulation and provide only qualitative characteristics for the instrument under consideration.

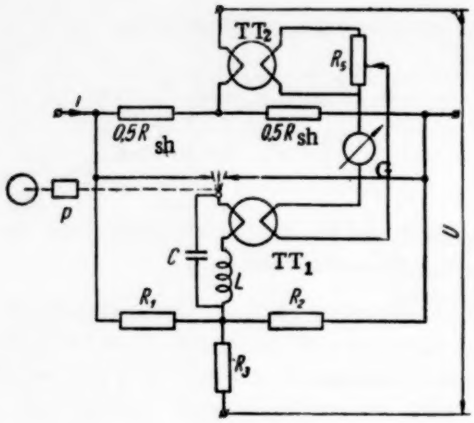


Fig. 7

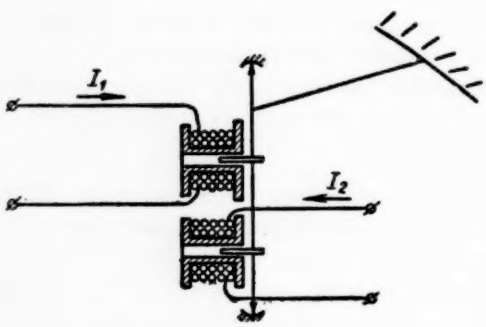


Fig. 8

For equal moduli of the compared voltages $U_1 = U_2 = U$ the output alternating voltage is equal to

$$U_2 = 2kU\left(\sqrt{\frac{1+\cos\varphi}{2}} - \sqrt{\frac{1-\cos\varphi}{2}}\right) = \tag{9}$$
$$= 2kU\left(\cos\frac{\varphi}{2} - \sin\frac{\varphi}{2}\right).$$

For a 90° phase difference indication $\varphi = 90° \pm \delta$, where δ is the angular error. Then:

$$U_2 = 2kU\left[\cos\left(45 \pm \frac{\delta}{2}\right) - \sin\left(45 \pm \frac{\delta}{2}\right)\right] \simeq \mp\frac{\sqrt{2}}{2}kU\delta, \tag{10}$$

where δ is in radians.

In practice the resulting voltages are not exactly equal to the geometrical sum and difference of the input vectors, due to the differences between the elements of the summing and subtracting circuits. The error due to the difference between these elements can be eliminated if the sum and difference voltages are not obtained simultaneously, but sequentially in the same summing circuit. The sequential following of these voltages in the same circuit can be obtained by periodically reversing the phase of one of the compared voltages which is fed to the phase sensitive circuit with a frequency considerably lower than that of the voltages under test [8].

The periodic phase reversal is best achieved by dividing one of the voltages into two equal parts (Fig. 4) by means of a divider 1 and alternately feeding these voltages, which are in opposition, to the input of the phase-sensitive circuit 2 by means of an automatic switch.

With such an arrangement of the indicator circuit, a lack of a commutation frequency voltage at the output of detector 3 corresponds accurately to a 90° phase difference between the compared voltages irrespective of the stability or differences in the circuit elements, or the variations in the supply voltage. In the main, the error of the circuit is determined by the threshold of sensitivity, which can easily be lowered by amplifying the output ac voltage, which is proportional to the angular error. The fact that the circuit has a single channel provides the possibility of raising its selectivity by introducing a band-pass filter for the modulated voltage, without at the same time decreasing the zero stability of the circuit.

The latter statement is obvious since the filter affects equally the sum and the difference when they are equal. Hence, any amplitude distortions cannot change the relation between the sum and the difference, when their phase difference is 90°, and therefore affect the zero reading. The phase distortions in the filter or any other stages cannot affect the accuracy of reading since the system has a single channel.

On the basis of the modulation principle, a highly stable selective 90° phase difference indicator was developed whose schematic is shown in Fig. 5. One of the voltages U_1 to be compared is fed to the divider 1 input and the other voltage U_2 to the grid of double triode 3 of the phase sensitive stage. Reversed-phase voltages are fed from the automatic switch 2 in turn to the other grid of double triode 3.

The output voltage of the phase-sensitive stage is taken off the cathode load and fed to the tuned amplifier 4 and then to detector 5. The alternating voltage produced by the detector with a frequency equal to that of the switching is amplified in amplifier 6 and then rectified by means of the second automatic switch 8, which works in synchronism with the first switch and then measured on galvanometer 7. The zero reading of the galvanometer indicates a 90° phase difference.

Polarized relays with two pairs of synchronized contacts with their windings fed from multivibrator 9 are

used as automatic switches and tuned to a frequency of 2 - 3 cps.

It should be noted that the inequality of the half periods of switching does not affect the accuracy of measurement, since at the instant when the voltage sum and difference are equal, i.e., when there is a 90° phase difference, the low frequency envelope of the output voltage in the phase-sensitive stage will be lacking for any ratio of the two switching half periods (providing that $\Omega \ll \omega$). The latter phenomenon is one of the basic advantages of a single-channel modulation system.

An accurate equality of the reversed phase voltages is judged by the zero reading of the galvanometer when the second grid of the phase-sensitive stage is grounded. In fact, when the voltages are equal there will be no amplitutde modulation at the output of the tube which will be indicated by the galvanometer zero reading [9].

In this modulation circuit, a sensitivity of the order of several seconds of the arc is obtained when measuring a 90° phase difference with a highly stable zero reading.

Thermoelectric phase indicators, whose thermal emf is proportional to the angular error in measuring a 90° phase difference.

Several thermoelectric phase-sensitive circuits are known. The most accurate results for measuring a 90° phase shift are obtained with a transformerless thermoelectric wattmeter circuit [10], which is shown in Fig. 6.

The mean value of the thermal emf at the output of the circuit will be $E = 4kI_1I_2 \cos\varphi$, where I_1 and I_2 are the effective values of the heater current. When a reading of a 90° phase difference is obtained $\varphi = 90 \pm \delta$ and:

$$E = \mp 4kI_1I_2\delta. \tag{11}$$

The sensitivity of the circuit for 10 ma currents measured by means of thermal transducers with a constant $K = 0.1$ mv/ma^2 amounts to $S_\delta = 2 \cdot 10^{-4}$ mv/1 ".

If a galvanometer type 167303 of the Hertz company with a voltage sensitivity of $2.5 \cdot 10^{-8}$ v/mm is used it is possible to obtain a phase variation sensitivity of the order of 2-3". Such a sensitivity, however, can only be attained with a sinusoidal waveform of the compared currents, since otherwise considerable errors may arise. The use of filters produces, as in the case of electromechanical indicators, an additional error caused by phase shifts in the filters. The above circuit can be used for measuring 90° phase differences over a wide frequency range with a small harmonic content. If one of the currents under test is varied over wide limits (for instance owing to a varying load) errors arise due to differences in the thermal transducer characteristics, since a complete compensation of this error is only possible at a single point.

This error can be eliminated by using a switching phase-sensitive circuit with a single operative thermal transducer TT_1 (Fig. 7).

If the circuit is switched at a frequency of 0.5 cps an amplitude modulated current will flow through the heater of the thermal transducer, in a manner similar to the modulated phase-indicator described above. When the switching period is comparable to the thermal constant of the transducer, the thermal emf will have an ac and dc component.

$$E = E_{-} + E_{\sim}. \tag{12}$$

The dc component of the thermal emf is compensated by the auxiliary transducer TT_2, whose heater current does not vary in the switching process. The moving system of the galvanometer oscillates under the effect of the ac component so that:

$$E_{\sim} = 4k_{M}k_{T}KI_1I_2\delta, \tag{13}$$

where $k_{M} = \frac{1}{\sqrt{(1-4\eta^2)+(4\eta\beta)^2}}$ is the coefficient of damping of the ac component due to the mechanical inertia of the galvanometer [11]; $k_T = \frac{1}{4\pi f_k \tau}$ is the coefficient of damping of the ac component due to the thermal inertia of the transducer [12].

At a switching frequency of 0.25 cps and a thermal constant of the transducer of 1 sec, for instance:

$$k_T = \frac{1}{4\pi \cdot 0.25 \cdot 1} = \frac{1}{\pi}.$$

If a Hertz galvanometer type 167303 is used:

$$k_M = \frac{1}{(1-4\cdot 0.5^2)^2+(4\cdot 0.5\cdot 0.5)^2} = 1.$$

The sensitivity of the circuit for measuring 10 ma currents amounts to

$$S_\delta = 0.7\cdot 10^{-4} \text{mv}/1''.$$

The advantage of this circuit consists in the possibility of decreasing the errors due to higher harmonics by means of an LC filter. An additional error due to the phase shift in the filter is absent in this circuit as in the modulation phase-indicator (Fig. 5).

Measuring a 90° phase difference at infrasonic frequencies. In connection with the use of infrasonic frequencies, at the present time, in industry and in various scientific investigations the problem of measuring 90° phase differences at frequencies of the order of 0.5 cps and lower should be considered. Infrasonic frequencies are used in particular for obtaining amplitude-phase characteristics of most diverse automatic control systems in the range of 0.01 to 10 cps. These characteristics are obtained by means of "aphographs" - automatic rectangular-coordinate recording compensators. The "aphographs" require a simple aperiodic device for measuring 90° phase differences in a very wide frequency range independently of the supply voltage variations. Compensation circuits for measuring 90° phase differences cannot be used owing to their sensitivity to frequency variations. Instruments of the electromechanical group (for instance, electrodynamic instruments) cannot be used either, because their natural frequencies will be too close to the measured ones.

The basic error of the "aphographs" with respect to amplitude amounts to 5%, and with respect to the angle to 5°; it is therefore advisable to use with them a simple, although less precise, 90° phase shift indicator. It was suggested that such a device could consist of a double measuring mechanism of an instrument whose torque has an rms relation to the current. A moving iron instrument is the simplest device of this kind. The schematic of such an indicator is shown in Fig. 8. If currents I_1 and I_2 are sinusoidal and have a phase difference of 90°, the instantaneous values of the torque in the first and second measuring mechanisms, providing they are identical, will be equal to:

$$M_1 = kI_1^2 - kI_1^2 \cos 2\omega t, \quad M_2 = kI_2^2 - kI_2^2 \cos(2\omega t - 180°).$$

The total torque for currents I_1 and I_2 with a phase difference of 90° will be equal to $M = 2kI^2$ providing $I_1 = I_2 = I$, i.e., providing there is no ac component. For an angular error of $\pm\delta$ in measuring a 90° phase shift the total torque will be equal to

$$M = M_{st} + kI^2 \sin 2\delta \sin 2\omega t.$$

Thus, for an inaccuracy of δ in measuring a 90° angle there will arise in the torque, and hence in the deflection angle, an ac component whose amplitude will be proportional to δ. The amplitude of the ac deflection will be equal for small angles to [10]:

$$\alpha_{\sim\max} = \frac{2kI^2\delta}{W\sqrt{(1-4\eta^2)^2+(4\eta\beta)^2}},$$

where $\eta = T_0/T_b$; T_0 - the period of natural oscillations of the instrument's moving part; T_b - the period of current I; β - the degree of damping.

The relative value of the ac deflection (in %) will be

$$\gamma_{\alpha\sim} = \frac{\alpha_{\sim\max}}{\alpha_{-}} = \frac{\delta\cdot 100}{\sqrt{(1-4\eta^2)^2+(4\eta\beta)^2}}.$$

In order to reduce the effect of frequency on $\alpha_{\sim}$ it is necessary to decrease the period of natural oscillations of the instrument. A mirror galvanometer is suitable for such purposes.

LITERATURE CITED

1. A. M. Melik-Shakhnazarov, G. A. Alizade, and T. M. Aliev, "An ac compensator with a phase-sensitive null indicator, "Instruments and Assemblies [in Russian] (Izd. INTI, 1956) No. P-56-458.
2. K. B. Karandeev and L. Ya. Mizyuk, "Classification and properties of electronic ac indicators," Problems of Automation and Measurement Techniques [in Russian] (IMA, Akad. Nauk UkSSR, 1955) No. 3.
3. M. I. Levin, "Vector-meters for balanced ac bridges," Trudy MGIMIP, [in Russian] (Mashgiz, 1950) No. 2.
4. L. Ya. Mizyuk, A Phase-sensitive Indicator Circuit. Scientific Notes [in Russian] (IMA, Akad. Nauk UkSSR, 1953) Vol. II, No. 2.
5. L. Ya. Mizyuk, Electronic Vector-meters with a Switched Operation. Scientific Notes [in Russian] (IMA Akad. Nauk UkSSR, 1954) Vol. III, No. 2.
6. E. G. Atomalyan, A Phase-sensitive Electronic Indicator. Collection of Scientific Papers [in Russian] Moscow Mekh. Insta., 1953) No. 3.
7. D. E. Polonnikov, New Phase-sensitive Electronic Amplifier Circuits. Collection of Papers on Automation and Remote Control [in Russian] (Acad. Sci. USSR, 1956).
8. Yu. A. Skripnik, author's certificate No. 114891, dated October 30, 1957.
9. Yu. A. Skripnik, author's certificate No. 119257, dated July 5, 1958.
10. P. P. Ornatskii, Bulletin of the Kiev Polytechnic Institute 13 (1954).
11. P. P. Ornatskii, Bulletin of the Kiev Polytechnic Institute 25 (1957).
12. P. P. Ornatskii, Izmeritel'naya Tekh. 5 (1958).

AN INDICATOR OF MAXIMA

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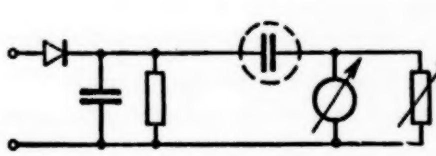
Bulgarian People's Republic

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 29-30, August, 1960

Maxima (minima) cannot be accurately measured in flat characteristics by means of voltmeters or ammeters.



The accuracy of these measurements is increased if the so-called compensation peak galvanometer, previously developed by the author [1], is used. The principle of operation of this instrument consists of the following. The measured ac voltage is rectified and fed to a dc voltmeter. By tuning the measuring circuit, an approximately maximum value of the voltage is measured by the instrument. By means of an external adjustable dc voltage source the greater part of the rectified voltage is balanced out. The voltmeter thus reads only the unbalanced remainder of the voltage. Thus, a smaller range is required to be measured by the voltmeter, i.e., it can be made more sensitive. Next, the maximum of the curve is again obtained. The introduction of a compensating voltage is equivalent to making the curve sharper.

In fact, let ΔU denote the voltage variations across the tuned circuit which are produced by changing capacitance C in the circuit by an amount of ΔC. The slope of the curve can be represented by the ratio $\Delta U/U$, where U is the basic voltage. Since, owing to the balancing, U has been decreased, the ratio $\Delta U/U$ increases, which is equivalent to making the curve sharper.

By repeating several times the procedure of finding an approximate maximum, an accurate maximum can be found. It is obvious that the accuracy of measurement is determined by the capacitor stability, voltmeter (galvanometer) sensitivity, and the voltage and frequency stability of the generator.

The effect of the generator instability can be eliminated by the method suggested by I. A. Maslarov, which consists in using for the compensating dc voltage the rectified generator voltage.

In this instance, as complete balancing is approached, the two voltages, i.e., the basic and the compensation voltages are equalized, and hence, the variations due to the instability of the generator voltage are eliminated. It is, however, impossible to eliminate the frequency variation of the generator by this method, since the voltage across the tuned circuit changes with frequency, but the compensation voltage remains the same. However, due to the flatness of the response characteristic frequency, instability has but a small effect. A certain disadvantage of this method consists of the fact that compensation is attained manually.

This defect can be eliminated if the suggested maximum indicator, consisting of a dc galvanometer connected to a differentiating RC circuit, is used.

In this maximum indicator, similarly to the compensation peak galvanometer, the voltage is rectified. As the circuit is tuned and the maximum approached, the dc voltage rises, thus increasing the galvanometer reading. When the maximum (minimum) is reached the galvanometer deflection is reversed. The value of the deflection depends on the slope of the characteristic and the speed of scanning.

A relatively large capacitance is chosen for the differentiating network (see figure). The electrolytic capacitors used for this purpose should have small leakages. For the resistance of the differentiating network, the resistance of the galvanometer is used, thus the galvanometer sensitivity is retained.

Since the time constant of the circuit is small, the instrument works in the ballistic condition. In this method only the direction of the galvanometer deflection matters and not the initial reading.

The instrument sensitivity can be varied by means of shunts.

Both circuits, that of the peak galvanometer and the maximum indicator, provide a greatly increased accuracy in measuring the maximum value of a voltage when the characteristic is flat, with the first circuit providing greater accuracy and the second being extremely simple.

These circuits can be used in a Q-meter type KV-1 which is used for measuring small values of Q.

LITERATURE CITED

1. A. I. Aizenshtein, Elektrichestvo, 12 (1956).

HIGH AND ULTRAHIGH FREQUENCY MEASUREMENTS

A NEW METHOD OF AUTOMATIC FREQUENCY CONTROL

L. D. Bryzzhev

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 30-32, August, 1960

In recent years,the stability of quartz crystal oscillators has beenraised by means of automatic trimming with the aid of a bridge circuit [1, 2].

The most interesting is the method described in [2], in which the circuit operates as a normal oscillator when there is no error signal. This method, however, requires a large number of complicated electronic circuits and possesses a large inertia.

It is shown below that automatic frequency trimming can be achieved by means of a bridge circuit much simpler and with a considerably smaller inherent inertia.*

The new method is based on the idea of feeding the amplified signal,which arises in the bridge diagonal, when the frequency varies to the oscillator circuit without any other transformation in order to provide an additional reactance,which stops the frequency drift.

Let us examine the suggested method as applied to a quartz oscillator which we found to be satisfactory in practice [3].

Fig. 1. shows the schematic of this oscillator, which uses a transistor and has no automatic trimming. In this circuit the quartz resonator is equivalent to an inductance L_e with a series resistance R_e.

In order to form a bridge circuit a capacitor C_3 is connected in series with the resonator and a mesh consisting of inductance L, resistance R and capacitance C is added to the circuit.

The bridge is balanced when

$$\frac{L}{L_e}=\frac{R}{R_e}=\frac{C_3}{C}=A.$$

If $A \gg 1$ the effect of the parallel circuit on the operation of the oscillator is very small.

When the frequency of the quartz oscillator varies,an error signal arises in the bridge diagonal in the form of voltage ΔU of the basic frequency, proportional to the frequency deviation and 90° out of phase with the voltage across capacitor C_3. The phase of the voltage across the diagonal changes by 180° when the sign of the frequency deviation is reversed.

Let us see what will happen if voltage ΔU is fed from the bridge diagonal through an amplifier to points a and b in the transistor input circuit.

Since voltage ΔU is 90° out of phase with respect to the voltage across capacitor C_3, it is also 90° out of phase with respect to the voltage across C_2, i.e., to the input voltage of the transistor.

The supply of this voltage to the input of the transistor makes it reactive. Depending on the direction of the phase shift,the transistor becomes equivalent to an inductance or a capacitance. With correct phasing,the frequency will thus be trimmed to bring it back to the nominal.

In practice,this method of trimming requires the use of an amplifier with input and output transformers.

In order to avoid this complication,the circuit shown in Fig. 3 was used. In this circuit the bridge diagonal voltage is amplified by a factor of n and fed to another reactive transistor, connected in parallel with the oscil-

* Paper read at the All-Union Scientific Conference dedicated to the Radio Day of May 17, 1960.

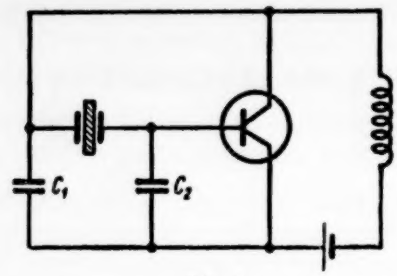


Fig. 1.

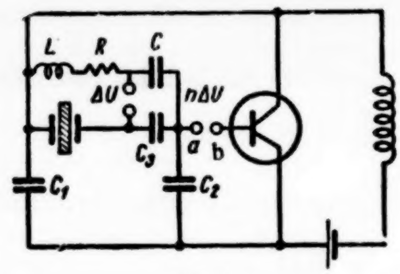


Fig. 2

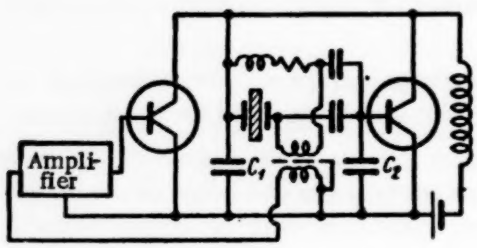


Fig. 3.

lating transistor. In other respects this circuit is similar to the one already described.

Let us evaluate the degree to which the frequency stability is improved by this method when the frequency deviations are due to variations of capacitance C_1, caused by the instability of the capacitor or variations in the collector capacity of the transistor produced by supply voltage variations.

Let us assume that the frequency variations without autotrimming are equal to:

$$\Delta\omega_0 = -k\Delta C_1. \tag{1}$$

Let us represent the relation between reactive capacity and frequency in the autotrimming circuit by:

$$\Delta C_R = p\Delta\omega. \tag{2}$$

The positive sign takes into account the phasing required for stabilization.

The combined operation of the two effects can be represented by:

$$\Delta\omega = -k(\Delta C_1 + \Delta C_R). \tag{3}$$

Inserting (1) and (2) in (3) we obtain the coefficient of frequency stabilization:

$$\frac{\Delta\omega_0}{\Delta\omega} = kp + 1, \tag{4}$$

which shows by what factor the frequency variation is decreased by means of autotrimming.

Equation (4) is similar to the well-known relations for automatic frequency control systems with proportional regulation.

The values of coefficients k and p, calculated for $C_3 = C_2$, are:

$$k \simeq \frac{\omega C_q}{2C_1^2}; \qquad p \simeq \frac{2C_1^2}{\omega C_q} n, \tag{4a}$$

where n is the voltage gain of the amplifier.

By inserting these values in (4) we obtain the coefficient of frequency stabilization in the form:

$$\frac{\Delta\omega_0}{\Delta\omega} \simeq n + 1. \tag{5}$$

Without automatic trimming n = 0, and the circuit operates as an ordinary oscillator.

An experimental testing out of the circuit at 100 kc (Fig. 3) has confirmed the correctness of our reasoning and calculations. The feeding of the amplified error signal to the input of the reactance transistor decreased the effect of variation of capacitances C_1 and C_2 and that of the supply voltage on the frequency of the oscillator according to the derived relationship.

It was, however, impossible to obtain a higher stabilization coefficient than 10, since any further increase in gain of the amplifier led to oscillations at the resonant frequency of the amplifier.

This problem was solved by using,in the amplifier,a crystal filter tuned to the frequency of the oscillator.

By working with a quartz filter and an amplifier with a gain of about 50, stray oscillations were avoided and the effect of the supply voltage instability was reduced by a factor of 45.

Under these conditions the frequency of a quartz oscillator with a crystal which had a Q-factor of 10^7 was detuned by voltage variations of 10% by a factor of $3 \cdot 10^{-11}$.

Filters with resonators which had Q factors of 10^4 and $5 \cdot 10^6$ were also tested. In the latter case lagging in the operation of the autotrimmer was observed.

It is interesting to compare the above circuit with the normal bridge quartz oscillator circuit (Meacham bridge).

In Meacham's circuit the whole of the feedback passes through the bridge diagonal, thus leading to an additional frequency instability owing to the phase changes in the amplifier.

In our circuit,the amplifier only amplifies the error signal and hence the amplifier phase stability is of secondary importance.

The above method of autotrimming is suitable not only for stabilizing oscillations, but also for sychronizing oscillators against reference frequencies.

In all the cases,when it is possible to control the reactance element by means of an ac voltage of the operating frequency displaced in phase by 90°, it should be done in preference to controlling it with dc voltage according to the normal practice.

The connecting of the reaction element with an RC network provides by itself the effect of a capacitance or inductance; the controlling dc voltage only varies their value. This fact leads to an instability of the initial conditions and to their being affected by the supply circuit of the reactance element.

In order to decrease the effect of the supply condition, circuits with a parallel connection of two elements with opposite reactances are used. The adjustment of such circuits is, however, very difficult and does not in practice provide the required stability.

An ac control is free from this defect and leads in compensation circuits directly to the formation of an equivalent capacitance or inductance depending on the sign of the unbalance.

LITERATURE CITED

1. P.G. Sulzer, PIRE, 6 (1955).
2. Lea Norman PIRE, 11 (1955)
2. L. D. Bryzzhev and V. N. Tito, Izmeritel'naya Tekh., 1 (1956)

INVESTIGATING A METHOD OF MEASURING FREQUENCY DEVIATIONS OF FM SIGNALS BY MEANS OF BESSEL FUNCTION ZEROES

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Translated from Izmeritel'naya Tekhnika, No. 8, pp. 33-35, August, 1960

The above method, as it is known, consists of recording by means of an indicating instrument the zero amplitudes of the carrier, or side frequencies, in the spectrum of a frequency-modulated signal, amplitudes which are proportional to the Bessel functions of the first kind of the modulation index. The index of modulation being equal to one of the roots of this function. If the index of modulation is known, it is possible to determine the deviation, since the modulating frequency can be measured with the required degree of accuracy.

This method can be applied by means of a narrow-band receiver or a spectral analyzer.

The use of a receiver is very difficult if the mean frequency of the FM signal is so unstable that during the measurement it drifts outside the receiver band, which normally occurs in the ultrasonic frequency range (30-300 Mc).

In the case of a spectral analyzer the instability of the frequency leads to a horizontal displacement of the FM spectrum image on the screen of the oscilloscope tube; this displacement, as a rule, does not interfere with the measurements.

The principle of the application of the spectral analyzer is described in the technical literature, but to the best of the author's knowledge, the errors in measuring the frequency deviation and the effect of spurious phenomena (spurious amplitude modulation, and modulation distortion) on the measurement results have not been considered. The present article deals precisely with these questions.

For measuring the deviation the author used a spectral analyzer with a bandwidth of the intermediate frequency amplifier of the order of 20 cps at 110 kc. The minimum sweep frequency was about 0.5 cps.

With these parameters the resolution of the spectral analyzer provides spectral discrimination with a minimum modulating frequency of 500 cps. The oscillogram shows the disappearance of the carrier frequency (Fig. 1.), which is proportional to $J_0/(\Delta\omega/\Omega)$, at a modulating frequency of 2 kc.

Error of the method. If the bandwidth of the dynamic filter characteristic is considerably small that the modulating frequency (the resolution of the spectral analyzer is sufficiently great), the measurements are made without a systematic error, independently of the choice of the parameters of the mixer, the intermediate frequency 100 kc amplifier, and of other elements of the spectral analyzer.

The random errors are due to the inaccuracy of visual determination of the instant when the amplitude of any of the spectral components becomes zero.

In order to clarify this question let us examine the behavior of the first derivative of the Bessel function of the n-th order near its root K_m.

After simple transformations it is possible to obtain from the formula

$$\frac{dJ_n\left(\frac{\Delta\omega}{\Omega}\right)}{d\left(\frac{\Delta\omega}{\Omega}\right)} = \frac{-n}{\frac{\Delta\omega}{\Omega}} J_n\left(\frac{\Delta\omega}{\Omega}\right) + J_{n-1}\left(\frac{\Delta\omega}{\Omega}\right)$$

$$\text{for } \frac{\Delta\omega}{\Omega} = K_m$$

the following expression $$\frac{dJ_n(K_m)}{J_0(0)} = \frac{J_{n-1}(K_m)}{J_0(0)} K_m \frac{d(\Delta\omega)}{\Delta\omega} \cdot 100\,\%, \qquad (1)$$

Root number	%
1	1,3
2	1,9
3	2,3
4	2,7
5	3,0

Fig. 1

Fig. 2

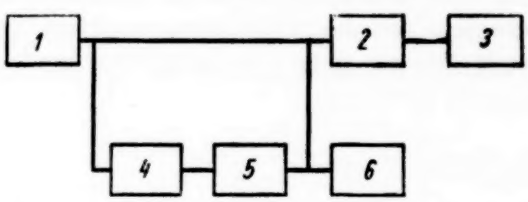


Fig. 3. 1) audio frequency oscillator; 2) standard signal generator; 3) spectral analyzer; 4) multiplier; 5) phase shifter; 6) nonlinear distortions measuring device.

where n can assume the values of 0, 1, 2, ... Since $[\lim/(m \to \infty)] K_m J_{n-1}(K_m) = \infty$, it will be seen from (1) that the higher the number of the root, the greater will be the amplitude increment in the spectral component for the same variation of the deviation around the value which corresponds to the root, and the smaller will be the random error of the visual determination when this component turns into zero.

The relative increment of the function $J_0(K_m)$, which is most frequently used, for various values of m when the deviation is changed by 1% is given in the Table.

Hence, if the amplitude of the carrier frequency, which is proportional to $J_0(0)$ exceeds considerably the dimensions of the oscilloscope screen, a variation of the deviation by ± 0.5% with respect to the value corresponding to K_m can be easily detected. The oscillogram in Fig. 2 corresponds to such a deviation variation.

Thus the random error of this method can be made smaller than ± 0.5%. (See Table)

Let us examine the effect of spurious amplitude modulation. In this instance the signal reaching the spectral analyzer has the form:

$$U(t) = A_0[1 + m\cos(\Omega t + \varphi)]\sin\left(\omega_0 t + \frac{\Delta\omega}{\Omega}\sin\Omega t\right). \quad (2)$$

After spectral expansion we obtain:

$$U(t) = A_0\left\{\left[J_0\left(\frac{\Delta\omega}{\Omega}\right)\sin\omega_0 t + mJ_1\left(\frac{\Delta\omega}{\Omega}\right)\sin\varphi\ \cos\omega_0 t\right] + \right.$$
$$+\left[J_1\left(\frac{\Delta\omega}{\Omega}\right) + J_0\left(\frac{\Delta\omega}{\Omega}\right)\frac{m}{2}\cos\varphi + \right. \quad (2a)$$
$$\left.\left. + J_2\left(\frac{\Delta\omega}{\Omega}\right)\frac{m}{2}\cos\varphi\right]\sin(\omega + \Omega)t + \ldots\right\}.$$

It is possible to conclude from (2) for $\varphi \neq 0$ that if $\Delta\omega/\Omega \doteq K_m$, the amplitude of the carrier oscillations will not equal zero, but will reach a minimum near that value. Let us evaluate the measurement error assuming that for its minimum value $\Delta\omega/\Omega = K_m$.

It will be seen from (2a) that the carrier frequency signal has an amplitude proportional to:

$$\sqrt{J_0^2\left(\frac{\Delta\omega}{\Omega}\right) + m^2\sin^2\varphi J_1^2\left(\frac{\Delta\omega}{\Omega}\right)}. \quad (2b)$$

If the derivative of this expression is equated to zero and the solution of the expression is sought in the form of $\Delta\omega/\Omega = K_m + \epsilon$, where ϵ is a small increment, we shall obtain

$$\varepsilon = \frac{m^2\sin^2\varphi}{K_m(1 - m^2\sin^2\varphi) + \frac{m^2}{K_m}\sin^2\varphi}. \quad (2c)$$

Thus if we assume that the minimum of a signal of frequency $\omega/2\pi$ occurs at $\Delta\omega/\Omega = K_m$, the error of

measurement will be

$$\frac{d\,(\Delta f)}{\Delta f}=\frac{m^2\sin^2\varphi}{K_m^2-\sin^2\varphi\, m^2\,(K_m^2-1)}\cdot 100\,\% . \tag{3}$$

This expression has a maximum at $\varphi=\pi/2$ and will decrease with rising root number.

If we examine, for instance, a very unfavorable case when $\varphi=\pi/2$; $K_m = 2.40$, the first root of $J_0(\Delta\omega/\Omega)$, and the spurious amplitude modulation has a modulation coefficient of 30%, the measurement error will only amount to 1.7%.

If $\varphi = 0$ or 180° expression (2a) can be simplified:

$$U(t)=A_0\left\{J_0\left(\frac{\Delta\omega}{\Omega}\right)\sin\omega_0 t+J_1\left(\frac{\Delta\omega}{\Omega}\right)\left(1+\frac{m}{\frac{\Delta\omega}{\Omega}}\right)\sin(\omega+\Omega)t-J_1\left(\frac{\Delta\omega}{\Omega}\right)\left(1-\frac{m}{\frac{\Delta\omega}{\Omega}}\right)\sin(\omega-\Omega)t+\right. \tag{4}$$

$$\left.+J_2\left(\frac{\Delta\omega}{\Omega}\right)\left(1+\frac{2m}{\frac{\Delta\omega}{\Omega}}\right)\sin(\omega+2\Omega)t+J_2\left(\frac{\Delta\omega}{\Omega}\right)\left(1-\frac{2m}{\frac{\Delta\omega}{\Omega}}\right)\sin(\omega+2\Omega)t+\ldots\right\}.$$

It will be seen from the above expression that for $\varphi = 0$ and $\varphi = 180°$ it is possible to use for measuring the deviation any of the spectral components without fear of an additional error due to the spurious amplitude modulation. For $J_0\,(\Delta\omega/\Omega)$ this can be seen from (3). It is necessary, however, to take care of the stray zeroes which occur at

$$\frac{mK}{\frac{\Delta\omega}{\Omega}}=1, \tag{4a}$$

where K = 1, 2, 3, ...

For an experimental confirmation of these conclusions the frequency modulated signal was also amplitude modulated and then fed to the spectral analyzer. The device which provided the modulation had the facility of changing the initial phase of the modulated voltage.

Tests showed that in-phase and reversed-phase ($\varphi = 0$ and $\varphi = 180°$) modulation did not affect the accuracy of measurements. This was checked with $0< m< 70\%$.

For $\varphi=\pi/2$ and $0< m< 30\%$ the sprectral component of frequency $\omega/2\pi$ could not be reduced to zero, yet in measuring by the minimum of this signal noticeable errors were not discovered, i.e., in practice the minimum occurred at $\Delta\omega/\Omega \simeq K_m$. Measurements were made for the first five roots of $J_0\;(\Delta\omega/\Omega)$.

The impossibility of noticing the error calculated from (3) is due to the very shallow minimum which makes the random error much greater than the systematic error determined from (3).

Let us now examine the effect of the harmonics of the modulating voltage. If, for instance

$$\omega_i=\omega+\Delta\omega_1\sin\Omega t+\Delta\omega_2\sin(2\Omega t+\varphi), \tag{4b}$$

the signal of frequency ω will have the form

$$U_\omega\simeq A_0\sqrt{\left[J_0\left(\frac{\Delta\omega_1}{\Omega}\right)J_0\left(\frac{\Delta\omega_2}{2\Omega}\right)+2J_2\left(\frac{\Delta\omega_2}{2\Omega}\right)J_4\left(\frac{\Delta\omega_1}{\Omega}\right)\cos 2\varphi\right]^2+\left|2J_1\left(\frac{\Delta\omega_2}{2\Omega}\right)J_2\left(\frac{\Delta\omega_1}{\Omega}\right)\sin\varphi\right|^2}. \tag{5}$$

and if

$$\omega_i=\omega_0+\Delta\omega_1\sin\Omega t+\Delta\omega_3\sin(3\Omega t+\varphi), \tag{5a}$$

then:

$$U_{\omega} \simeq A_0 \left[J_0\left(\frac{\Delta\omega_1}{\Omega}\right) J_0\left(\frac{\Delta\omega_3}{3\Omega}\right) - 2J_1\left(\frac{\Delta\omega_3}{3\Omega}\right) J_2\left(\frac{\Delta\omega}{\Omega}\right) \cos\varphi \right] \tag{6}$$

Expressions (5) and (6) can be derived from the spectral expansions for the case of two modulating frequencies if it is assumed that $\Omega_2 = 2\Omega_1$ and $\Omega_3 = 3\Omega_1$.

In the case of the second harmonic at $\Delta\omega/\Omega = K_m$ the amplitude of the carrier frequency does not become zero for $\varphi \neq 0$, but attains a minimum near these values at $\Delta\omega/\Omega = K_m + \delta$. The value of δ was determined experimentally. For this purpose an equipment was assembled whose schematic is shown in Fig. 3. It will be seen from Fig. 3 that the standard signal generator was modulated by the fundamental frequency, and its harmonic, whose initial phase could be varied within the limits of $\pi/4$ - $3\pi/4$.

The measurements were made in the following manner: the sinusoidal modulating voltage without the addition of harmonics was varied until the spectral carrier frequency component became zero and $\Delta\omega/\Omega = K_m$. Next the second harmonic was added. The coefficient of nonlinear distortion k_f of the modulating voltage was measured by means of a nonlinear distortion meter. As the result of the addition of the harmonic with $k_f \leq 10\%$ the spectral component which was previously reduced to zero appeared again on the screen of the oscilloscope. Its minimum amplitude was, however, at the same value of K_m. This was checked for $k_f \leq 10\%$ with different phasing of the second harmonic and for five roots. Thus, if the minimum of the carrier amplitude is used for measurements, it is possible to assert that the spectral analyzer does not respond to the presence of the second harmonic.

In fact, the deviation in this instance will be expressed by two values $(\Delta\omega/2\pi)_{in}$ and $(\Delta\omega/2\pi)_{out}$ with:

$$\begin{aligned} &\Delta\omega_1 \leq \Delta\omega_{in} < \Delta\omega_1 + k_f \Delta\omega_1; \\ &\Delta\omega_1 - k_f \Delta\omega_1 < \Delta\omega_{out} \leq \Delta\omega_1 \end{aligned} \tag{6a}$$

Thus the error of measurement of the spectral analyzer can attain the value of k_f.

Conclusions. The above analysis of the error in measuring frequency deviation by means of the zeroes of the Bessel function and a spectral analyzer shows the following:

1. The error of measuring the deviation with a sinusoidal modulation and modulating frequencies over 500 cps does not exceed $\pm$ 0.5% and decreases with an increasing ordinal number of the root.

2. A random spurious AM leads to additional errors of measurement.

3. An in-phase and reversed-phase AM does not affect the accuracy of measurements.

4. The presence of the second harmonic in the modulating function at small values of($\Delta\omega_k/k\Omega$ (k = 2,3, ...) in the worse case leads to an error not exceeding the coefficient of nonlinear distortions.

The above method provides the calibration and checking of FM oscillators and standard signal FM generators over a wide range of deviations, and modulating frequencies with a high degree of precision (1 - 2%).

DECREASING THE READING ERROR IN DETERMINING THE PHASE DIFFERENCE BY MEANS OF THE LISSAJOUS FIGURES

V. S. Panchenko

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 36-38, August, 1960

It is known that if the deflecting plates of a cathode-ray oscilloscope receive two sinusoidal voltages of the same frequencies and amplitudes, but differing in phase, an image will appear on the oscilloscope screen, in a general case, in the shape of an ellipse. If the coordinates X and Y of the ellipse are superposed on a network representing the deviation of the beam image, the following equations can be obtained:

$$x = A \sin \omega t, \quad y = A \sin(\omega t + \varphi) \tag{1}$$

where x and y are the deviations of the beam image along the coordinate axes; A is the maximum deviation.

In order to determine the phase difference φ by the shape of the ellipse the following relation is normally used:

$$\varphi = \sin^{-1} \frac{a}{A}, \tag{2}$$

where a is shown in Fig. 1. Another method of determining φ can also be used, which consists in measuring the ordinate of one of the two intersection points of the ellipse with the axis: $x = A/\sqrt{2}$.

It follows from (1) that the values of the ordinates at these points a' and a" (Fig. 1) are equal to:

$$a' = A \cos(45° + \varphi), \quad a'' = A \sin(45° + \varphi), \tag{3}$$

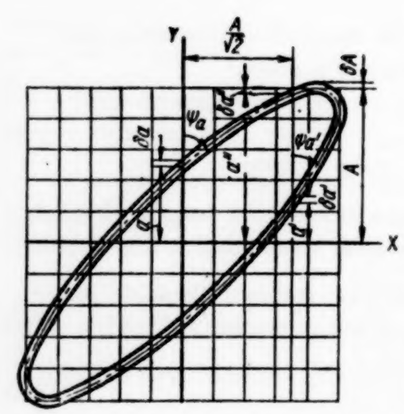


Fig. 1. Lissajous figures and the determination of the values used for measuring the phase differences and calculating the measurement errors.

whence

$$\varphi = \cos^{-1} \frac{a'}{A} - 45° \quad \text{or} \quad \varphi = \sin^{-1} \frac{a''}{A} - 45°. \tag{4}$$

Let us determine the value of the random error of measurement and its relation to φ for measurement methods based on the relationships (2) and (4).

The random error of measurement (below we only have in mind this component of the total error of measurement) is determined by the errors of measurement in a, a', a" and A, which depend on definition and the width of the beam path on the screen and the width of the graduation lines. They also depend on the angles between the coordinate axes and the tangents to the ellipse at the points of its crossing the axes. Let us assume that if the angle $\psi_a = 90°$ the measurement of the length is made with the maximum random error equal to half the width of the beam trace t. If $\psi_a \neq 90°$ the error increases by the factor $1/\sin \psi_a$ which is derived from simple geometrical considerations. Hence

$$\delta A = \frac{t}{2}, \quad \delta a = \frac{t}{2 \sin \psi_a} = \frac{t}{2} \sqrt{1 + \cos^2 \varphi} \tag{5}$$

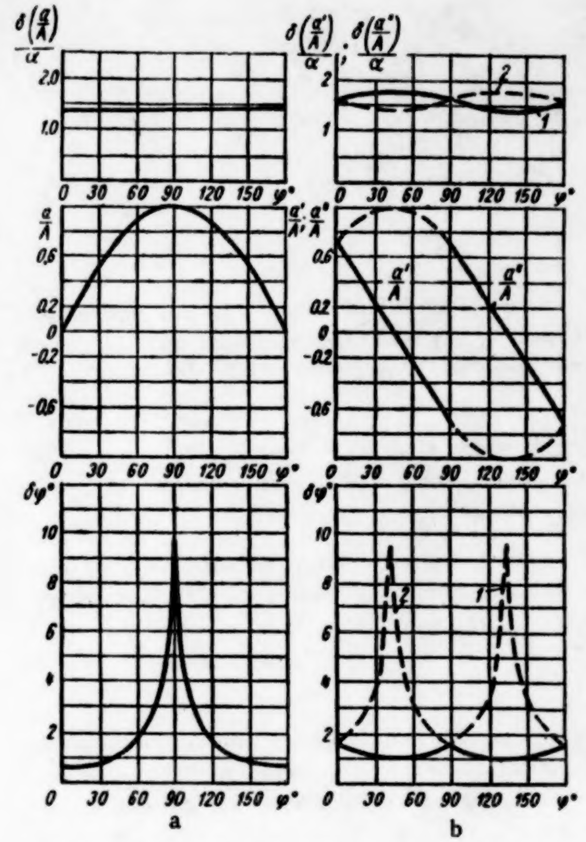


Fig. 2. Relations of the errors in determining the ratio of the measured lengths, the ratios proper and the errors of readings to the value of the measured phase differences for $\alpha = 0.01$. a) For the method normally used; b) for the method described in this article when ordinates a' (1) and a'' (2) are measured.

since

$$\operatorname{ctg}\psi_a = \frac{dy}{dx}\Big|_{x=0} = \cos\varphi. \tag{5a}$$

Errors δa and δA will provide when (2) is used the maximum error in determining the phase angle $\delta\varphi$ which is represented by the expression:

$$\sin(\varphi+\delta\varphi) = \frac{a+\delta a}{A+\delta A} \simeq \frac{a}{A} + \delta\left(\frac{a}{A}\right). \tag{6}$$

For $\varphi \to 90°$ small changes in a/A correspond to large changes in φ. Hence, let us find $\delta\varphi$ by applying Taylor's formula to the left-hand side part of (6). By taking only the first and second order terms we obtain:

$$\delta\varphi^2 \sin\varphi + 2\delta\varphi\,|\cos\varphi| - 2\delta\left(\frac{a}{A}\right) = 0, \tag{6a}$$

whence

$$\delta\varphi = \frac{-|\cos\varphi| + \sqrt{\cos^2\varphi + 2\delta\left(\frac{a}{A}\right)\sin\varphi}}{\sin\varphi} \tag{7}$$

$$\left(\frac{a}{A}\right) = \sqrt{\left(\frac{\delta a}{A}\right)^2 + \left(\frac{a\delta A}{A^2}\right)^2} = \alpha\sqrt{2}$$

(α is a parameter which characterizes the oscilloscope tube and is equal to the ratio of the beam image width $\underline{t}$ to the ellipse dimension $2A$)

In (6) and (7) the signs in front of the terms have been chosen so that the solution of the equations is real and positive.

For $\varphi \le 60°$ when $\frac{2\delta(a/A)\sin\varphi}{\cos^2\varphi} \ll 1$ it follows from (7) that

$$\delta\varphi' = \frac{\alpha\sqrt{2}}{|\cos\varphi|}. \tag{8}$$

Expressions (7) and (8) determine the relation of the maximum error of measuring the value of the phase difference and the value of parameter α. Moreover (7) holds for $0 < \varphi < 180°$ and (8) for $60° \varphi \ge 120°$.

In a similar manner, we obtain for (4) the following expressions:

$$\delta\varphi = \frac{-\sin(45°+\varphi) + \sqrt{\sin^2(45°+\varphi) + 2\delta\left(\frac{a'}{A}\right)|\cos(45°+\varphi)|}}{|\cos(45°+\varphi)|} \tag{9}$$

$$\delta\varphi' = \alpha\sqrt{1 + \frac{2}{\sin^2(45°+\varphi)}}, \tag{10}$$

which holds for $0 \le \varphi \le 90°$ and

$$\delta\varphi = \frac{-|\cos(45^\circ+\varphi)| + \sqrt{\cos^2(45^\circ+\varphi)+2\delta\left(\frac{a''}{A}\right)|\sin(45^\circ+\varphi)|}}{|\sin(45^\circ+\varphi)|} \tag{11}$$

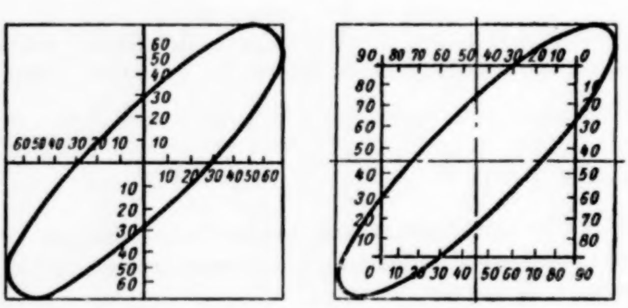
$$\delta\varphi' = \alpha\sqrt{1+\frac{2}{\cos^2(45^\circ+\varphi)}}, \tag{12}$$

which are sufficiently accurate for $90^\circ \le \varphi \le 180^\circ$.

On the basis of (7), (9) and (11) the relations $\delta\varphi = f(\alpha, \varphi)$ are given in Figs. 2a and b for the methods of measurement under comparison. It was assumed that for the most widely used tubes with a screen diameter of 130 mm the following parameters hold: A = 50 mm, τ = 1 mm, α = 0.01. From these relations the following conclusions can be drawn.

1. The above method of determining phase differences by means of Lissajous figures provides measurements with an error not exceeding $\pm 2^\circ$ for $55^\circ \ge \varphi \ge 125^\circ$ if $\alpha = 0.01$. For $\varphi = 90^\circ$ the error amounts to $\pm$ 9.6°; this is the reason for which the Lissajous method is considered inaccurate.

2. The method described in the article provides measurements of phase differences in the range of 0 to $\pm$ 180° with an error varying in the limits of $\pm$ 1 to 1.3°, also with an α = 0.01. For $0 \le \varphi \le 90^\circ$ it is necessary to measure the value of a' and for $90^\circ \le \varphi \le 180^\circ$ the value of a″. In either case in order to obtain the minimum error it is necessary to measure either ordinate a' or a″ whichever has the smaller absolute value. The relation $\delta\varphi = f(\alpha, \varphi)$ is shown for this case by a full line in Fig. 2b.



a b

Fig. 3. The appearance of calibrations for a direct reading of the phase differences. a) for the usual method b) for the described method of measurements.

If for the purpose of determining which quarter the phase angle is in, the variation of the slope angle of the major axis of the ellipse with respect to the coordinate axes is taken (in a manner similar to the one used in the normal method of measurements), relation (4) can be re-written as

$$\varphi_1 = \cos^{-1}\frac{a_s}{A} - 45^\circ, \tag{13}$$

where φ_1 is the angle referred to the first quarter; a_s - the ordinate which is smaller in its absolute value at the point of intersection of the ellipse with the coordinate axis: $x = A/\sqrt{2}$.

The result thus obtained is due to the form of the relationship between the lengths measured on the screen and angle φ. In the middle graphs of Figs. 2a and b the character of these relations is shown for the two methods under comparison. It will be seen from these graphs that a higher measurement accuracy by means of the method here described is due to the higher slope, and the smaller sensitivity to φ is due to the stability of the slope of the curve sections (3) used, which are shown in a solid line.

Although the angle ψ_a varies between 45 and 90° for variations of φ between 0 and 90° (the smaller the and ψ_a, the larger will the error be in α and φ), and angles $\psi_{a'}$ and $\psi_{a''}$ vary in the range of 45 - 35° for the same variations of φ, the errors caused by these variations in measuring a' and a″ and in determining ratios a'/A and a″/A are insignificant (see the top graphs in Figs. 2a and b).

For the method here described the inaccuracy in setting the maximum deviation along the X axis will produce an additional error.

It can be shown that this error for a maximum setting error of $\tau/2$ is equal to α, and for $\alpha = 0.01$ amounts to 0.57°. If this error is taken into account the total error will change only a little (by 0.15°) owing to the addition in the quadrature of the random errors.

The well-known advantage of the measuring method based on relation (2), consists of the possibility of

reading the phase difference angles directly by means of a special scale calibrated in angular units and placed in front of the oscilloscope screen. The method here described also possesses this advantage. Figure 3 shows the appearance of calibration scales calculated from (2) and (3). In either case the reading of phase difference angles can be obtained from one of the four calibrated axes. Comparison of the calibrations shows that the accuracy of direct reading from these scales corresponds to the conclusions arrived at above.

LITERATURE CITED

1. V. P. Kovalev, Pribov. i Tekh. Eksp., 2 (1958)*

BOLOMETRIC HEADS FOR MEASURING POWER AT 1000 Mc

V. I. Krzhimovskii and V. V. Kshimovskii

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 38-40, August, 1960

The development of the UHF technique raises the problem of measuring power with greater accuracy, since power is one of the most important parameters in high-frequency systems.

Several properties especially useful for precision measurements are characteristic of a wire bolometer consisting of a thin metal wire which absorbs the UHF power; and therefore such bolometers can be recommended for these measurements.

For the connection of the bolometer into the high-frequency channel a bolometric head is used. The head is required for transmitting the measured high-frequency power to the bolometer, matching it to the transmission line, fixing the bolometer securely and connecting it to the measuring circuit.

Hence, the bolometric head is in the first place a transformer, which matches the bolometer impedance to characteristic impedance.

The quality of any bolometric head is represented by two basic parameters: its standing wave ratio in the operating frequency range, and the high-frequency energy losses in the walls of the head and the dielectrics.

In the decimeter and meter wavelength ranges coaxial lines with a characteristic impedance of 50 or 70 ohms are normally used, and the bolometric head must, therefore, have a coaxial input.

Wide-band heads are of special interest. They can be divided into two types: those which use one bolometer and those with two bolometers (symmetrical connection).

The bolometric heads examined in this article were designed for a low-power reference meter with an error of the order of 1%.

Such a head used for measuring UHF power had particularly strict requirements. The error due to the power reflected from the head input must be considerably smaller than 1% so that it could be neglected.

On the other hand, losses of high-frequency energy depend in the main on the material, the quality of the finish and surface area of the waveguide as well as from the quality and quantity of dielectrics; these losses can attain several percent. In this connection the problem of determining losses with the highest possible precision becomes of utmost importance, since the error of their determination makes a direct contribution to the general error of the set. The errors are usually expressed in terms of efficiency which is represented by the expression:

$$\eta=\frac{P_2}{P_1}.$$

* See English translation.

where P_1 is the power fed to the head; P_2–the power absorbed in the sensing element.

Let us now examine from the above point of view each one of the two types of wide-band bolometric heads developed by the D. I. Mendeleev All-Union Scientific Research Institute of Metrology. (VNIIM).

The design and characteristics of a wide-band bolometric head with one bolometer. In order to match the bolometer it is necessary to make the impedance at the point of connection of the bolometer purely resistive, and equal to the characteristic impedance. Let us examine the practical methods which would provide for the fulfillment of this condition.

Both calculations and experiments show that the input impedance of the length of line occupied by the bolometer is capacitative, hence,it is first of all necessary to compensate its equivalent capacitance. In order to decrease its value it is necessary to make the outside diameter of the coaxial line smallest at the place where the bolometer is connected. In order to compensate for the residual capacitance,an inductance is connected in series and made of a recess in the internal conductor; by changing the length and diameter of the recess,optimum operating conditions may be obtained (Fig. 1).

On the other hand in order to transform the high input impedance of the volumetric section, a combination of a stepped variation in the diameter of the external conductor with a cone shaped internal conductor was used (Fig. 2).

Two auxiliary elements C_c and L_{ch} are also required for connecting bolometer 1 to the measuring circuit. Capacitance C_c is formed by means of a mica packing 0.02-mm thick and is of the order of 1000 μf. The high frequency choke coil is glued directly onto the polystyrene washer and consists of six turns of 0.05-mm wire wound in a helix.

The head's input is made in the shape of a standard coaxial socket for a 75 ohm cable. For connecting the head to the measuring circuit the former is provided with an appropriate plug.

The above head has a standing wave ratio not less than 1.15 in the frequency range of 450-1100 Mc. The losses in the head were determined by means of the impedance method [2] for which purpose an adjustable head was made.

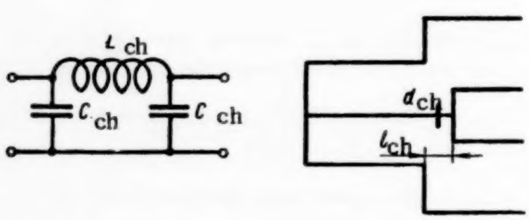


Fig. 1. Matching of the bolometer to the transmission line.

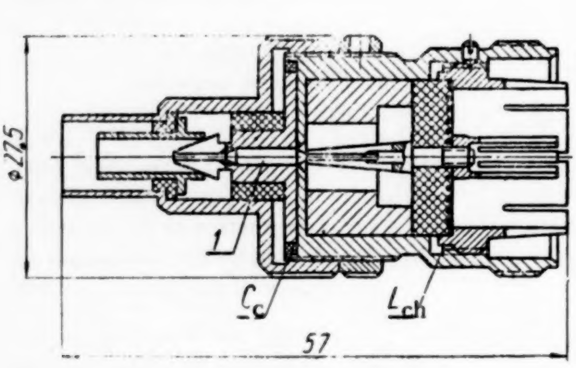


Fig. 2. A bolometric head with one bolometer.

The head with one bolometer had at 1000 Mc an efficiency not worse than 99.7% and its maximum error of measurement did not exceed 1.2%.

The head is designed to work with a bolometer type BP2-75 of 75 ohms developed by the VNIIM.

Construction and characteristics of a wide-band symmetrical bolometric head with two bolometers. Another possible version of a bolometric head is one with two symmetrically connected bolometers. This design has become popular abroad [1] owing to several valuable properties with which we shall deal below.

The symmetrical head (Fig. 3) consists of a T-piece which divides the input power into two approximately equal parts. A bolometer is connected into each of the T-piece arms. It will be seen from Fig. 3 that the bolometers are connected in parallel for high-frequencies and in series for dc. Thus,the resistance of each bolometer should be 150 ohms.

The bolometers are matched to the characteristic impedance of the line by means of an inductive recess and a tuning capacitor. The length of the inductive recess is chosen to make the input impedance inductive so that it could be then adjusted by the tuning capacitance

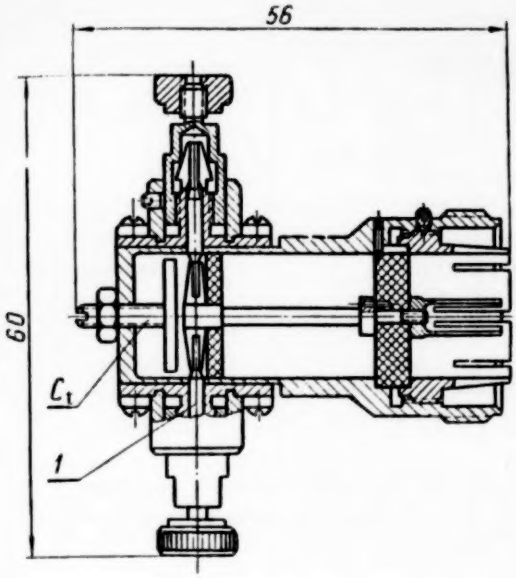


Fig. 3. A symmetrical bolometric head with two bolometers.

C_t for the smallest reflection coefficient in a given range of frequencies.

The blocking capacitances which serve to connect the bolometer to the measuring circuit have values exceeding 1000 $\mu\mu$f and represent small impedances at high frequencies.

Owing to the series connection of the bolometers in the measuring circuit there is no longer any necessity to have a high frequency choke which connects the external and the internal conductors. The head has an input made in the shape of a standard coaxial 75 ohms socket.

The above symmetrical head has a standing wave ratio not worse than 1.15 in the range of 30-2000 Mc. Tests have shown that its efficiency up to 1000 Mc remains better than 99.6%.

Bolometers BP1-150 of 150 ohms were used with the symmetrical head. These bolometers had a strict specification with respect to the variation of their resistance between different samples. A set of 40 bolometers with a resistance tolerance of ± 1% was manufactured, but subsequent tests of a head with different bolometers showed that this tolerance could be lowered to ± 3%, without appreciably affecting the standing wave ratio or the efficiency of the device. A series of tests of the relation of the standing wave ratio and efficiency to the changing of the bolometers in the head were carried out. The dispersion of the values of the standing wave ratio and efficiency was within the random measurement error limits.

It will be seen from the comparison of the two heads that the symmetrical head has a wider operating frequency range than the head with one bolometer. This is probably due to the fact that in the symmetrical head, 150 ohm bolometers are being used so that the impedance of each approaches that of the bolometric section to which it is connected. At the same time the 75 ohm transmission line is loaded by an impedance of the two bolometers connected in parallel which approximates the characteristic impedance. Moreover the absence of a choke coil facilitates the extension of the range. It should also be noted that the power fed to the head is divided between two bolometers thus extending the upper load limit and their overload capacity.

The above heads form part of the set of reference UHF power meters developed by the VNIIM. A. M. Brodskii, N. F. Serdyuk and M. V. Sakharova participated in the development of the head.

LITERATURE CITED

1. H. Rieck, Nachrichtentechnik, 11, No. 2 (1958).
2. R. Beatty and F. Reggia, J. Res. NBS, 54, No. 6 (1955).

OPTICAL MEASUREMENTS

MODULATION OF LIGHT BY MEANS OF AN ULTRAHIGH FREQUENCY (10^{10}cps)

G. S. Simkin, V. P. Naberezhnykh, and I. V. Lukin
Translated from Izmeritel'naya Tekhnika, No. 8, pp. 41-43, August, 1960

Among the various light modulators used for measuring lengths, the speed of light and other quantities, those based on the Kerr effect are the most prominent. It is important from the practical point of view,and scientifically interesting,to modulate light at very high frequencies (10^{10}cps).

Not all the substances which exhibit the Kerr effect are suitable for such modulation. For such modulation the substance must possess two properties: the molecules of the substance must have a small anisotropic relaxation time, and it must have a large Kerr constant for the possibility of a practical utilization of the substance as a light modulator.

It is well known that many substances in different phases (solid, liquid or gaseous) become double refracting under the effect of an electric field. It is also known that several substances in the solid phase as well as colloids have a large Kerr constant, these substances however, have a large relaxation time owing to their high intermolecular friction, and therefore are unsuitable for light modulation at 10^{10}cps.

Substances in a gaseous form normally possess a small relaxation time, but their Kerr constant is very small and therefore they are unsuitable in practice for light modulation.

Among the liquid substances nitrobenzene ($C_6H_5NO_2$) possess a large Kerr constant which is two orders higher than that of any other pure liquid.

Hence nitrobenzene can be used for modulating light at 10^{10}cps, providing the relaxation time of its molecules does does not exceed 10^{-11} sec.

Many investigators tried to determine the molecular relaxation time of various substances including nitrobenzene, but this problem cannot be considered completely elucidated at the present time. Thus,the relaxation times of nitrobenzene and other substances measured by means of different methods do not coincide.

The differences in the estimated relaxation times are clearly shown in the table [1].

It will be seen from the table that relaxation times measured by the inertia of the Kerr effect differ considerably from the values obtained by other methods. The response time of the Kerr effect, for instance, should not differ from the anisotropic relaxation time if both are obtained by the dispersion method. Nevertheless,the relaxation time of the nitrobenzene molecules measured by the response time of Kerr's effect by Hanle and Märks [2] gave a value of $\tau = 2.7 \cdot 10^{-9}$ sec. In this connection it is noted in [1] that Hanle and Märks results have no reasonable physical explanation and that intervals of time smaller than 10^{-9} sec could not be measured by the method used by these investigators.

Thus the problem of measuring the response of the Kerr effect remains unsolved, whereas its solution is of great scientific and practical importance. Light modulation by means of an ultrahigh frequency does not depend on an accurate determination of the relaxation time, but on the possibility of achieving this modulation.

With the object of solving this problem the Khar'kov State Institute of Measures and Measuring Instruments investigated the possibility of modulating light with a frequency of 10^{10}cps (λ = 3 cm) by means of a Kerr cell filled with nitrobenzene.

	Relaxation time ($\tau \cdot 10^{12}$ sec)			
Substance	Kerr effect	dispersion of electromagnetic waves	double refraction in the flux	Rayleigh line contour
Chloroform	38000	–	–	0.12
Chlorobenzene	–	2.1	0.33	0.3
Water	–	0.12	–	0.12
	–	023–1.4	–	0.12
Methyl alcohol	–	0.7	–	0.14
o-Dichlorobenzene	700	3.4	–	–
Nitrobenzene	2700	1.6	0.17	–
Benzene	–	–	0.24	0.24
Xylene	–	–	0.47	0.11

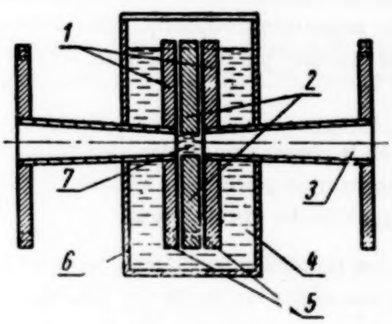


Fig. 1. 1) Flanges; 2) Kerr cell plates; 3) waveguide; 4) nitrobenzene; 5) mica; 6) vessel; 7) effective volume of Kerr cell.

The Kerr cell consisted of a section of a rectangular waveguide of a special construction.

The high frequency field (10^{10} cps) was applied to the cell by means of two rectangular waveguides which were made to taper towards each other and were connected to the Kerr cell by flanges.

For the filling of the Kerr cell with nitrobenzene and the passing of the light through it there are two rectangular openings in the side walls of the device. The effective volume of the cell is separated from the tapering waveguides by means of mica plates. The dc biasing voltage is fed to the cell's top wall which is insulated from the remaining walls by mica plates.

The whole assembly is placed in a metal vessel which is filled with nitrobenzene and whose side walls are made of glass (Fig. 1).

Thus,for a dc voltage the device is a normal Kerr cell. However,if an H_{01} type wave is produced in one of the waveguides,a high-frequency electric field of the same polarization as the dc field will be transmitted to the cell.

In order to reduce the reflections from the nitrobenzene layer, the width of the cell (the thickness of the nitrobenzene layer) was made approximately a quarter of a wavelength in nitrobenzene.

For the given geometrical dimensions of the cell (length l = 42 mm height η = 2.5 mm) the difference in the path of a normal and abnormal beam became equal to π when a dc biasing voltage of V_{max} = 4400 v (E = 17600 v/cm) was impressed on the cell.

A further reduction of height h led to a breakdown of the air in the narrow part of the waveguide by the high-frequency field and a very small luminous flux through the cell.

The alternating electric field strength in the narrow portion of the waveguide can be determined by the relation [3]:

$$E^2 = \frac{P \cdot 10^4}{6{,}63\, lL} \cdot \frac{\lambda_\partial}{\lambda_0}.$$

where P is the power fed to the cell, w; l - the length of the waveguide, cm; η - the height of the narrow portion of the waveguide, cm; λ_∂ - the wavelength in the waveguide, cm; λ_0 - the wavelength in free space, cm.

It will be seen from this formula that in order to obtain a field strength of the order of 3000-4000 v/cm, which is necessary to make the Kerr effect apparent, a relatively high powered high-frequency source is required (50-70 kw).

Obtaining continuous oscillations of that power is a fairly complicated problem. Moreover,experiments have shown that a Kerr cell absorbs some 20% of the impressed power. Hence,if a generator with this power is used in a continuously operating condition, the dissipation of energy in the cell will be excessive.

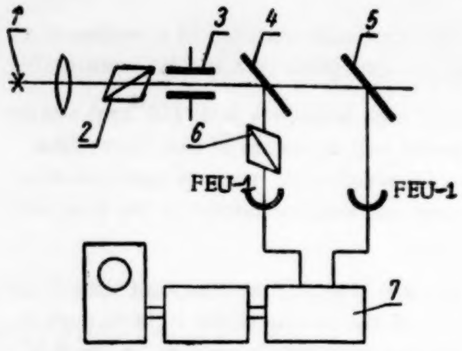


Fig. 2. 1) Light source; 2) polarizer; 3) Kerr cell; 4) semitransparent mirror; 5) mirror; 6) analyzer; 7) balancing circuit.

Fig. 3

With such a large energy absorption and relatively small dimensions of the cell, its cooling becomes difficult. A magnetron generator was therefore used in a pulsed operation whose pulse power amounted to about 50 kw. This generator provided a pulse field strength in the narrow portion of the waveguide of some 2700 v/cm.

The pulse repetition frequency was 1200 cps and the duration of each pulse amounted to 2.5 μ sec.

A direct determination of the effect of modulating light by means of a high frequency is very difficult, since an inertialess light demodulator would be required for this purpose. The use of a pulse generator simplified the technique of determining this effect for the following reasons.

It is known that when light is modulated over the nonlinear portion of the Kerr cell characteristic, a dc component arises in addition to the high frequency one, both being produced by the high frequency field. Since in this case the high frequency field was applied in the form of a pulse, the above dc component is modulated by the pulse repetition frequency. This circumstance made it possible to use ordinary photomultipliers.

In the testing we encountered several difficulties.

In the first place, we found that the electromagnetic wave, which is propagated in the waveguide, exerts on striking the mica and the nitrobenzene a noticeable pressure owing to its high power. As a result of this, a sound wave is propagated in the nitrobenzene which alters the refractive index of the nitrobenzene.

The variation of the refractive index of nitrobenzene at the pulse repetition frequency led to an additional modulation of light which passed through the cell. This modulation was of the same order of magnitude as the one produced by the Kerr effect.

In order to separate the two effects, experiments were conducted whose circuit is given in Fig. 2.

A light beam radiated by a mercury extra high-pressure lamp type SVDSh was transmitted through a polarizer and a Kerr cell. On leaving the cell, the light was separated into two beams by means of a semisilvered mirror. The analyzer was placed in one of the beams only so that the modulation due to the Kerr effect could only be detected in that beam. The modulation due to the sound wave was present in the two beams which were focused onto two photomultipliers.

The load resistor of one of the photomultipliers was placed in the anode and the load of the other in the cathode circuit so that the two voltages were in phase opposition. These reversed phase voltages were fed to grids of tubes which had a common load in their anode circuit. This anode load was connected to a grid of a cathode follower and then to an amplifier and an oscilloscope.

If the two beams are modulated by the same signals, the balancing circuit provides a full compensation of the interference pulses and transmits the pulses due to the Kerr effect in a pure form.

The proof that the pulses observed in this experiment were really due to the Kerr effect amounts to the following:

1) The relation between the amplitude of the pulses thus observed and the biasing voltage fed to the Kerr cell was the same as for the low-frequency modulation;

2) When the Nicol prisms were placed in parallel or crossed, different polarity pulses were produced (the biasing voltage was kept constant);

3) When working at the lower bend of the cell light characteristic the pulses corresponded to an increased amount of light, and when working at the upper bend, to a decreased amount. Figure 3 shows an oscillogram of

a pulse due to light modulation by a frequency of 10^{10}cps.

By measuring the value of the pulse it was possible to evaluate the value of the Kerr constant for the modulation frequency of 10^{10}cps; it was found to be 0.15 of that produced by a low frequency modulation.

From the knowledge of Kerr's constant at 10^{10}cps it was possible to determine the relaxation time. It was found to be about $3 \cdot 10^{-11}$sec.

This relaxation time value agrees well with that ($3.3 \cdot 10^{-11}$sec) obtained by us by means of the dispersion of electromagnetic waves of 3 and 1.25 cm.

The determination of Kerr's constant made it possible to evaluate the depth of light modulation by means of the 10^{10}cps. With the Kerr cell parameters given above, and a generator pulse power of about 50 kw, the depth of modulation was equal to 1%.

The low modulation coefficient is due to the fact that the phase of the high-frequency field changes considerably during the passage of light through the Kerr cell.

Conclusions. 1. As the result of these measurements, it was shown that nitrobenzene can provide light modulation at 10^{10}cps.

2. The value of the relaxation time of the nitrobenzene molecules is comparable to that obtained by means of dispersion of electromagnetic waves at the same frequency.

3. A greater depth of modulation can be obtained by a better choice of the dimensions and design of the cell, by raising the power of the UHF generator and by cooling the cell during operation.

4. This method of determining the relaxation time of nitrobenzene can also be used for determining the relaxation time of other substances.

LITERATURE CITED

1. I. L. Fabelinskii, Izvest. AN SSSR, Ser. Fiz., 9 (1945).
2. W. Hanle and O. Z. Mărks Phys., 114 (1939).
3. Transmission Lines for Centimeter Waves [in Russian] (Izd. Sovetskoe Radio, Moscow, 1951).

AN ACHROMATIC COMPENSATOR FOR DIFFERENCES IN THE PATHS OF RAYS

K. A. Khalilulin

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 44-47, August, 1960

For equalizing the difference in paths in the two branches of an interference instrument, glass wedge compensators are used. In its simplest form such a compensator consists of two refracting glass wedges with equal refracting angles placed in the opposite directions. One of these wedges is fixed and the other can be moved in a direction perpendicular to the optical axis of the instrument. The two wedges of this compensator make up a plane parallel plate; the movement of one of the wedges is equivalent to a change in the thickness of the plate.

Such a wedge compensator can only be used in a strictly monochromatic light; in white light the difference in the path introduced by the displacement of the wedge will differ for various wavelengths. This leads to a rapid blurring of the interference pattern.

The range of application of glass compensators for instruments is considerably widened if achromatic compensators are used.

Achromatic compensators are devices which preserve, during measurements, the position of the achromatic fringe in the system of interference fringes, and do not change the spectral composition, and hence, the shape of the

interference pattern over sufficiently wide limits of differences in the measured air path of the rays.

The idea of designing an achromatic compensator was expressed by Prof. N. P. Zavadskii as long ago as 1906 when he developed a range finder with a plane-parallel plate of variable thickness, and was subsequently confirmed by Academician V. P. Linnik in developing an interferometer for checking large machine parts. [1].

Some of the theoretical aspects of the achromatic compensators were developed by T. S. Kolomiitsova [2]. However, the theory proposed by T. S. Kolomiitsova is approximate and only holds for small refractive angles of the wedges. Moreover, the theory does not account for the variations of air thicknesses during the displacement of the moving system of the compensator.

Therefore, it is of interest to develope a complete theory of achromatic compensators without the above defects.

This article describes a rigorous theory of achromatic compensators of the difference in the path of rays, provides a design technique and cites the results of experiments.*

The theory of achromatic compensators can be developed on the basis of a new principle of achromatic correction of prismatic systems suggested by V. N. Churilovskii [3].

Let the prismatic system consist of m flat refracting surfaces deviating from the normal to the optical axis by angles $\vartheta_1, \vartheta_2 \ldots \vartheta_m$; moreover, surfaces with ordinals from 1 to k inclusive form the fixed part of the compensator; and those with ordinals from $k+1$ to l form the moving portion, which is displaced in the direction perpendicular to the optical axis (let us denote the value of this displacement by x); the surfaces with ordinals $l+1$ to m form another fixed part of the compensator. Let the angles formed by a ray with the axis be $\alpha_1, \alpha_2 \ldots \alpha_{m+1}$.

It can be shown that the path difference introduced by the compensator is expressed by the formula [4]:

$$\Delta = x(\sin\alpha_{l+1} - \sin\alpha_{\kappa+1}). \tag{1}$$

When passing from one light wavelength to another, Δ changes by the amount $d\Delta$:

$$d\Delta = x(\cos\alpha_{l+1}d\alpha_{l+1} - \cos\alpha_{\kappa+1}d\alpha_{\kappa+1}), \tag{2}$$

where $d\alpha_{l+1}$ and $d\alpha_{k+1}$ are dispersions of angles which arise due to the above change before and after the moving part of the compensator.

In order to make the compensator achromatic ($d\Delta = 0$) we obtain from the above the condition:

$$\cos\alpha_{l+1}d\alpha_{l+1} - \cos\alpha_{\kappa+1}d\alpha_{\kappa+1} = 0. \tag{3}$$

By means of the chromatic theory of prismatic systems it is possible to transform (3) to the following form:

$$\frac{\cos\alpha_{l+1}}{\xi_{l+1}}\sum_{s=1}^{s=l}\xi_s U_s - \frac{\cos\alpha_{\kappa+1}}{\xi_{\kappa+1}}\sum_{s=1}^{s=k}\xi_s U_s = 0. \tag{4}$$

The values of ξ_s and U_s are determined from the formulas:

$$\xi_{s+1} = \xi_s\frac{\nu_{s+1}\cos(\alpha_{s+1}-\alpha_s) - \nu_s}{\nu_{s+1} - \nu_s\cos(\alpha_{s+1}-\alpha_s)}, \tag{5}$$

$$U_s = \frac{\sin(\alpha_{s+1}-\alpha_s)}{\nu_{s+1} - \nu_s\cos(\alpha_{s+1}-\alpha_s)}\left(\frac{1-\nu_{s+1}}{\mu_{s+1}} - \frac{1-\nu_s}{\mu_s}\right). \tag{6}$$

* The work was carried out under the guidance of Prof. V. N. Churilovskii.

where μ_s is the coefficient of dispersion of the s-th medium;

$$\sum_{s=1}^{s=m} \xi_s U_s = 0. \tag{6a}$$

In addition to fulfilling condition (4) the requirement for the achromatization of the entire compensator must also be fulfilled:

$$\nu_s = \frac{1}{n_s}. \tag{7}$$

This condition, however, is fulfilled automatically if the compensator is equivalent in its operation to one of several plane parallel plates.

Formulas (1), (4) and (7) contain all the required conditions for designing an achromatic compensator. Formula (2) serves for checking.

In order to illustrate the above theory of a achromatic compensator let us examine the design of one of its possible versions.

The schematic of an achromatic compensator is given in Fig. 1. It consists of four wedges, the external fixed wedges serve to build out the internal moving wedges to plane parallel surfaces, thus, automatically fulfilling condition (7). The moving wedges have unequal refracting angles oriented in the opposite directions. The mobile wedges may be glued together along their sides.

Wedges K_1 and K_2 are made of crown glass and wedges K_3 and K_4 of flint glass.

Let us derive a formula for a practical design of an achromatic compensator.

The difference Δ in the path of rays introduced by the compensator is expressed according to (1) as:

$$\Delta = x(\sin\alpha_6 - \sin\alpha_3), \tag{8}$$

where $\underline{x}$ is the displacement of the moving system.

The conditions of achromatization of the value Δ are determined from expression (4).

In our case we have:

$$\frac{\cos\alpha_3}{\xi_3} \sum_{s=1}^{s=2} \xi_s U_s = \frac{\cos\alpha_6}{\xi_6} \sum_{s=1}^{s=5} \xi_s U_s. \tag{9}$$

The formulas (9) and (8) thus obtained make it possible to design an achromatic compensator.

On the basis of Fig. 1 we have the following initial data for the computation:

$$\begin{gathered} \alpha_1 = \alpha_2 = \alpha_4 = \alpha_5 = \alpha_7 = \alpha_8 = 0; \\ \xi_1 = \xi_2 = \xi_4 = \xi_5 = \xi_7 = \xi_8 = 0. \end{gathered} \tag{10}$$

By applying (5) and (6) let us expand the summations of expression (9). We shall obtain for the auxiliary quantities U_s that

$$\begin{gathered} U_1 = U_4 = 0; \\ U_2 = U_3 = -\frac{\sin\alpha_3}{1 - \nu_1\cos\alpha_3} \cdot \frac{1-\nu_1}{\mu_1}; \\ U_5 = -\frac{\sin\alpha_6}{1 - \nu_2\cos\alpha_6} \cdot \frac{1-\nu_2}{\mu_2}. \end{gathered} \tag{11}$$

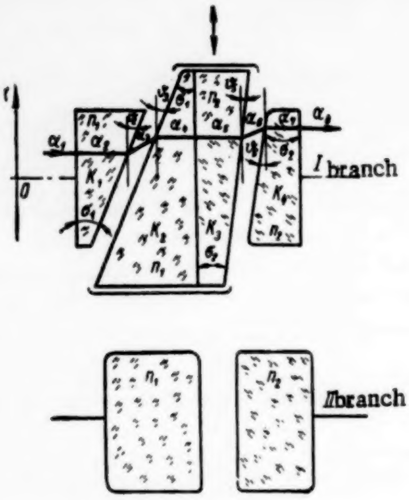


Fig. 1

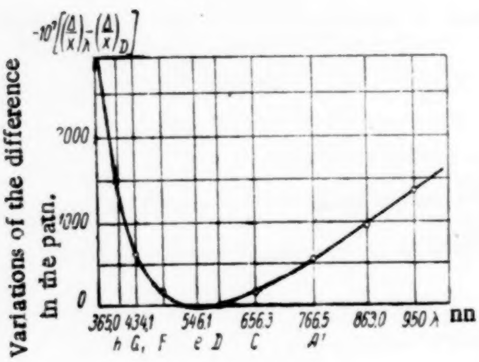


Fig. 2

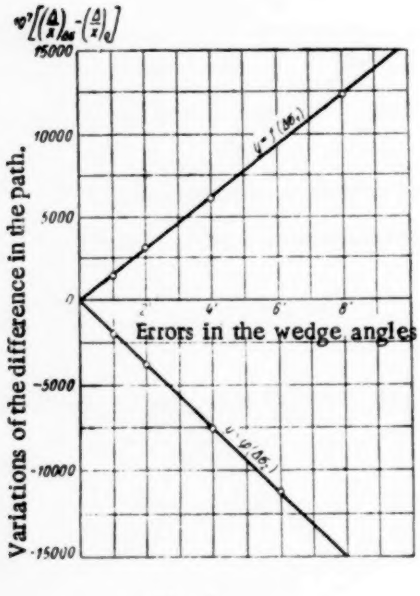


Fig. 3

From formula (5) we have:

$$\xi_3=\frac{\cos\alpha_3-\nu_1}{1-\nu_1\cos\alpha_3};$$
$$\xi_6=\frac{\cos\alpha_6-\nu_2}{1-\nu_2\cos\alpha_6}. \tag{12}$$

It follows from (11) and (12) that after transformation we can obtain from (9):

$$\frac{\cos\alpha_3\sin\alpha_3}{\cos\alpha_3-\nu_1}\cdot\frac{1-\nu_1}{\mu_1}=\frac{\cos\alpha_6\sin\alpha_6}{\cos\alpha_6-\nu_2}\cdot\frac{1-\nu_2}{\mu_2}. \tag{13}$$

Solving with respect to $\sin\alpha_3$ and taking into account (8) we obtain for the computation of an optical system of a compensator the following equations:

$$\Delta=x(\sin\alpha_6-\sin\alpha_3); \tag{14}$$

$$\sin\alpha_3=\frac{(1-\nu\ )\mu_1}{(1-\nu_1)\mu_2}\bullet\frac{\sin\alpha_6\cos\alpha_6}{\cos\alpha_3}\cdot\frac{(\cos\alpha_3-\nu_1)}{(\cos\alpha_6-\nu_2)}. \tag{15}$$

These formulas can be used for finding the unknown values of α_3 and α_6 by means of iterations: if an approximate value of α_3 is known, it becomes possible to determine α_6 from (14) and then find a new more accurate value of α_3 from (15).

By performing this iteration several times, we can determine the unknown with an accuracy which is satisfactory for practical purposes.

When the iteration is completed, there only remains to be calculated the angles $\vartheta_1, \vartheta_2, \dots \vartheta_7$ from the following formulas:

$$\vartheta_1=\vartheta_4=\vartheta_7=0;$$
$$\tan\vartheta_2=\tan\vartheta_3=\frac{\nu_1\sin\alpha_3}{\nu_1\cos\alpha_3-1};$$
$$\tan\vartheta_5=\tan\vartheta_6=\frac{\nu_2\sin\alpha_6}{\nu_2\cos\alpha_6-1}. \tag{16}$$

The wedge refracting angles σ_1 and σ_2 are determined from:

$$\sigma_1=\vartheta_2;\quad \sigma_2=\vartheta_5. \tag{17}$$

Let us give an example of a numerical calculation by means of the above formulas.

Let our compensator be required to work in the range of $\Delta = 200\lambda \simeq 0.1$ mm, and the full displacement $\underline{x}$ of the wedges be equal to 5 mm, i.e., $\Delta/x = 0.02$. The compensators are made of glass K-8 (1.5163) and TF-1 (1.64750).

From calculations made by means of logarithmic tables we find the following values of the wedge refracting angles of the compensator: $\sigma_1 = 4°26'28''$ and $\sigma_2 = 1°46'58''$.

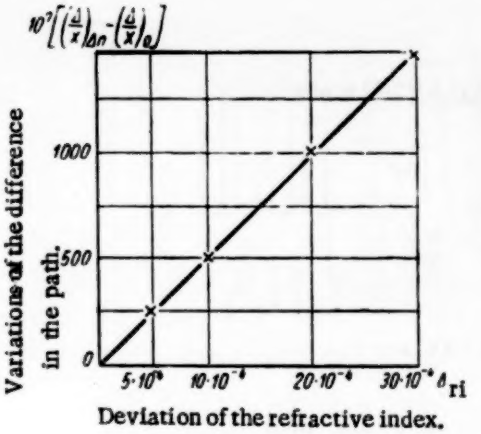


Fig. 4

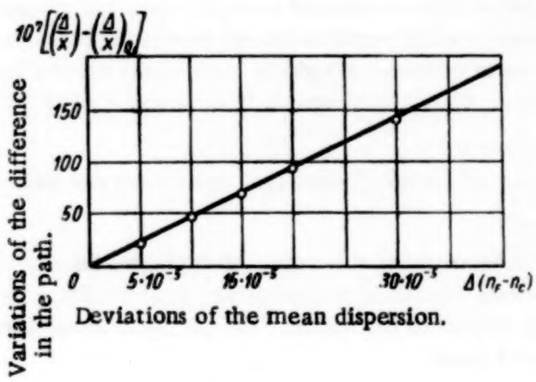


Fig. 5

The path difference corresponding to a displacement of the compensator by 1 mm for all the wavelengths can be determined by a trigonometrical calculation of the rays.

From the results thus obtained let us plot a graph (Fig. 2) where along the x axis we shall plot wavelengths λ in micromicrons and along the y axis the differences in the path which correspond to a displacement of the compensator by 1 mm$[(\Delta/x)_\lambda - (\Delta/x)_D]$ in 10^7.

It follows from Fig. 2 that the designed compensator has a good achromatic correction.

The results of the investigations of the effect on the achromatic correction of the errors in the wedge angles, the deviations of the refractive indexes and the value of the mean dispersion in the variations of the computation value Δ/x are given in Fig. 3, 4 and 5.

In order to determine the range of operation of an achromatic compensator one can use the formula given below[4]:

$$\frac{d\Delta}{\Delta} = \frac{1}{\mu_1-\mu_2}\left(\frac{d\bar{n}_1}{dn_1} - \frac{d\bar{n}_2}{dn_2}\right), \tag{18}$$

where μ_1, μ_2 are the coefficients of dispersion of the different types of glass in the compensator; $d\Delta$ - error in measuring the difference in the path;

$$dn = n_F - n_C\,; \qquad d\bar{n} = n_D - n_C\,. \tag{18a}$$

Tests have shown that with the help of achromatic compensators it is possible to measure without any corrections the difference in the air path of about 0.1 mm, i.e., of some 200 fringes. The value of the measurement error amounts to 0.1 of a fringe.

LITERATURE CITED

1. V. P. Linnik, Opticomechanical Industry [in Russian] (1946) No. 2, Sborn. Lonitomash (Mashgiz, 1948) Book 7.
2. T. S. Kolomiitsova, "Phenomenon of interference in white light with the presence of glass in the path of the interfering rays," Author's Report of a Dissertation, [in Russian] (GOI, 1953).
3. V. N. Churilovskii, "The theory of apochromatic prismatic systems for a remote technically accurate setting," Optical Instrument-Making (design and investigation) [in Russian] (LITMO, 1954) No. 11.
4. K. A. Khalilulin, "Investigation of certain questions regarding the interference method of measuring distances," Author's Report of a Dissertation [in Russian] (LITMO, 1956).

PHYSICOCHEMICAL MEASUREMENTS

A LABORATORY CHROMOTOGRAPHIC GAS ANALYZER

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and E. I. Zemskova

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 47-49, August, 1960

The All-Union Scientific Research Institute of the Oil Industry has developed a chromatographic gas analyzer for analyzing multicomponent gas mixtures. The analyzer is widely used in the oil processing chemical industry. The peculiarity of the gas analyzer consists in the use of effective adsorbents making the chromatographic separation of the components possible at room temperature. Thus, it was possible to develope a small and simple instrument.

The operation of the analyzer is based on the combination of the distributive (gas and liquid) and adsorption chromatography.

It is known that distributive chromatography consists of a heterogeneous system of two phases, the mobile phase (gas) and the stationary phase (liquid). The stationary phase consists of a nonvolatile, high-boiling point liquid usually spread over a solid substance which is inert with respect to adsorption. The partition occurs due to different solubilities of the gas mixture components in the liquid phase.

The adsorbent developed by us differs from the normal type by the fact that the liquid phase is spread over a solid carrier which is active with respect to adsorption, instead of being inert, and which consists of an active, coarse-grained silica gel (ACSG), which possesses good partition properties with respect to hydrocarbon gases.

The ACSG is treated with a highly polar liquid such as dimethylformamide at a rate of 40 g of the substance to 100 g of silica gel.

The effective separation of complex gas mixtures by means of this adsorbent without a temperature field is due to the combination of the adsorbent properties of silica gel and the selective dissolving properties of the liquid phase.

Carbon dioxide is used as a carrier gas by evaporating it from its solid phase contained in a Dewar flask. Carbon dioxide can also be obtained by evaporating it from its solid state contained in a special small 2 liter autoclave. If the autoclave is loaded with solid carbon dioxide and sufficiently well sealed the pressure developed in it amounts to 50-70 atm. One autoclave loading provides the operation of the instrument for 2-3 weeks.

The schematic of the gas analyzer is shown in Fig. 1. The instrument consists of four chromatographic columns 1, 2, 3 and 4, a measuring burette 5 type VTI, measuring burettes with bubbling type absorbing devices 6, 7, filled with a 40% solution of caustic potash, a rheometer 8 for measuring the speed of the carrier gas flow, adsorption pipettes 9 and 10 type VTI-2 for determining the content of carbon dioxide and oxygen and a system of stopcocks.

In order to increase the length of the adsorbent layer, the chromatographic columns are made in the form of two V-shaped tubes connected in series. The length of each leg of the tube is 400 mm and its diameter 8-10 mm. Columns 1 and 2 are filled with active coarse-grained silica gel, treated with dimethylformamide diluted in 3 to 4 times the amount of petroleum ether. The entire amount of silica gel is uniformly soaked in the solution, and then dried over a water bath until all traces of petroleum ether have been removed.

In order to speed up the removal of petroleum ether it is possible to combine the heating with the evacuation of the bulb which contains the soaked silica gel by means of a vacuum oil pump.

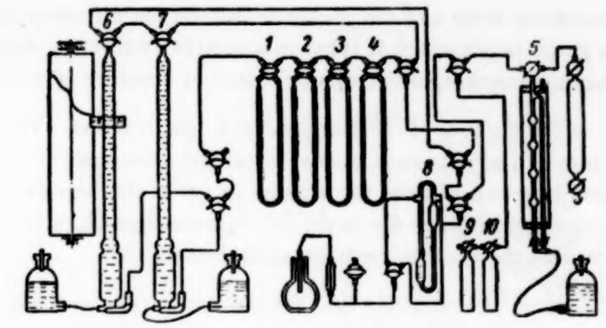


Fig. 1

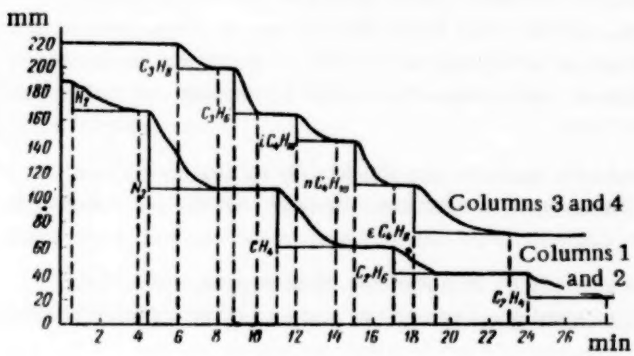


Fig. 2

Column 3 which is filled with activated carbon grade KAD, is used for separating hydrogen, nitrogen and methane. The ground carbon (0.25-mm grains are selected) is first dried in a drying oven at 120-140°C and then activated again in vacuum for 5-6 hours at 300°C.*

Column 4 is filled with silica gel MSM from which all traces of acid has been washed away, and the silica gel dried making it possible to separate without any further treatment ethane and ethylene.

The instrument can thus determine the following components of a gas mixture: carbon dioxide and oxygen by the adsorption method; hydrogen, nitrogen, methane, ethane, ethylene, propane, propylene, butane, isobutane, the amount of butylenes, isopentane, normal pentane and the amount of amylenes by the chromatographic method.

Since a volume-chromatographic method of identification is used, the various components leave the column at different times each hydrocarbon having its own characteristic time. In order to determine these values the instrument is calibrated beforehand. For this purpose the column is coated with a known hydrocarbon and the time each one leaves the column and the interval between them is observed. The time of leaving is measured from the instant the carrier gas enters the column.

The analytical procedure. A 100-ml sample of the tested gas is drawn into the measuring burette 5. In the absorbing pipettes 9 and 10 the content of carbon dioxide and oxygen is determined. The remaining 20-25 ml of gas are passed to columns 1 and 2 for chromatographic analysis, where without separation hydrogen, nitrogen, methane, ethane and ethylene are taken off to the measuring burette 7 and kept there for further analysis, but the hydrocarbons C_3, C_4, and C_5 are separated and leave in the following sequence: propane, propylene, isobutane, normal butane, an amount of butylenes, isopentane, normal pentane and an amount of amylenes.

On leaving the column, the binary mixture of the carrier gas and the components under test enter the measuring burette 6, where carbon dioxide is adsorbed in the caustic potash solution and the amount of the deposited component is measured in the upper graduated part of the burette. The first part of the analysis which consists in determining the hydrocarbons C_3, C_4, and C_5 takes about 30-40 min. Next, the gas which remained in burette 7 is analyzed. This gas is passed to columns 3 and 4. At first, hydrogen, nitrogen and methane are separated in column 3 and then ethane and ethylene in column 4. This part of the analysis takes 20-25 min. The total time spent on the analysis amounts to about one hour.

The above chromatographic gas analyzer was taken as a model for the mass production of instrument KhL-2 designed by the Special Design Office of the ANN.

The instrument if supplied from 220 v 50 cps mains. Its overall dimensions are 840 x 825 x 340 mm, and its weight is 20 kg.

The schematic of this instrument does not differ from that of the instrument described above.

The instrument is supplied with a device for automatic recording of the analysis results based on a direct measurement of the alkali level in the burette by means of a servosystem using the photoelectric principle.

* Experiments in separating hydrogen, methane and nitrogen were made by O. V. Zolotareva.

The movement of the carriage carrying the illuminating lamp and the photocell behind the meniscus of the liquid produces a recording of the characteristic on graph paper which is fixed to a vertically rotating drum. As the result of the analysis, a curve typical for the volume chromatographic characteristic is obtained (Fig. 2).

The number of the steps in the curve corresponds to the number of the components in the mixture. The height of the steps represents the volume of the components. The existence of horizontal stretches indicates the complete separation of the components since during these intervals of time the volume of gas in the burette does not change. In practice, instead of the horizontal stretches between the components, sometimes slightly inclined portions of the curve are obtained, which are caused by the insufficiently clean carbon dioxide.

The slight variations of the alkali level due to the influx of impurities into the burette are registered by the carriage of the photoelectric system thus producing the slightly inclined lines.

In order to calculate the gas composition, the height of the steps is measured and their total height taken as 100%. Moreover, two corrections are made: one for the refraction of the measured gas in the burette, which is calculated from the corresponding calibration curve, and the other takes into account the impurities in the carbon dioxide. For its evaluation the volume of the gas which flows into the burette during 1 min due to the impurities in the carbon dioxide is determined beforehand; this value is multiplied by the flow out time of each component and then subtracted from the computed volume.

The efficiency of the chromatographic analysis in the columns was checked by testing known mixtures of hydrogen with hydrocarbons for C_1 to C_5 inclusive. The error of measurement in each case did not exceed 1% abs.

A comparison of the analysis of commercial gases made by means of the chromatograph and of the TsIATIM and Podbil'nyak's rectification equipments produced good agreement attained by two methods based on different principles.

The comparison of results obtained by the automatic recording method and by visual observation of the changes of the volume of gas in the burette also provided good agreement.

During the one and a half years of use in the gas laboratory of the All-Union Scientific Research Institute of the Oil Industry the chromatographic gas analyzer provided over 600 analyses of various industrial gases.

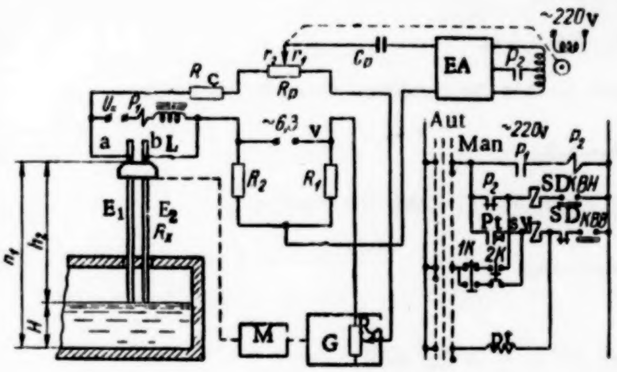
AN AUTOMATIC METHOD OF DETERMINING THE LEVEL OF MOLTEN SUBSTANCES

Yu. M. Abdeev, L. V. Golovinskii, and E. G. Limonova

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 49-51, August, 1960

The automation of measuring the level of metal melts (slag) in laboratories and industrial smelting ovens is especially important. It is, however, impossible to use for this purpose the level indicators employed in industry, including those based on radioactivity, due to the high temperatures involved, the thickness of the oven walls and the corrosive media.

A level indicator for an electric zinc ore-smelting oven is described in [1]. An additional graphite (measuring) electrode is inserted into the oven through an opening and is moved by a servo relay system in such a manner that its lower end always touches the upper level of the molten metal without disuniting it from the latter. The electrode is coupled to a rheostat transducer which is connected to an automatic electron bridge circuit. This method of measurement has an important defect, since the destruction of the electrode by burning, its shortening is not taken into account, thus bringing into the instrument readings an error which rises with time. Such a level indicator can only be used if it includes an automatic correction of its readings affected by the shortening of the electrode, a correction which is rather difficult to achieve.



The level indicator described in [2] is a periodically operating instrument and it has a narrow measuring range.

Below, we describe a level indicator (see Figure) developed by the author of this article for automatic continuous measurement of the level of various transient melts. The main advantage of this indicator is its differential method of measurement, which eliminates the error due to the shortening of the electrodes caused by their burning.

Two servo operated measuring electrodes E_1 and E_2 made of a conducting material of a high resistivity (ρ = 1500-15000 ohms·mm^2/m) and a low temperature resistance coefficient, are inserted through an opening in the top of the oven and serve as transducers. Electrodes made on the basis of silicon carbide or graphite can be used, as for instance those made of "glowbar" or "silite" materials.

Both electrodes are fixed in one holder, but they are insulated from each other; the diameter of the electrodes and the distance between them is chosen so that the resistance of the molten substance between the electrodes when they touch the surface of the melt is considerably smaller than the total resistance of the electrodes.

The electrodes can be displaced vertically by motor M. The relay servo system is similar to the one V. S. Lerner [1] suggested previously and provides the displacement of the electrodes according to the changing of the level of the melt in such a manner that the electrodes always touch with their ends the surface of the melt. If the length of the electrodes becomes unequal, for instance, due to burning, then one of them will touch the surface and the other will be immersed.

If the electrodes or one of them is disconnected from the surface, relay P_1 is de-energized and through its normally open contacts disconnects the supply to relay P_2, which operates switch SD thus starting motor M which lowers the electrodes.

When the electrodes touch the surface of the melt, relay P_1 operates and connects relay P_2 which opens the supply circuit of switch SD and stops the movement of the electrode.

In order to prevent the electrodes sinking too deeply into the molten substance when the level of the melt rises (although this will not introduce an error in the measurements, it will shorten the life of the electrodes) the time relay PT sends every 5–15 min a pulse for the lifting of the electrodes, which closes the supply circuit of switch SU, thus making motor M lift the electrodes. In order to prevent a simultaneous operation of contacts SD and SU the PT relay supply circuit has a normally closed contact of switch SD inserted in it.

The rheostat transducer is coupled to the motor M through reducing gear G and its control resistance R_c is proportional to distance h_1, i.e., $R_c = k_1h_1$.

The total resistance of the electrodes between points a and b is proportional to distance h_2, i.e., $R_x = k_2h_2$, where k_1 and k_2 are coefficients of proportionality.

The resistances R_c and R_x are connected into the measuring circuit of the ac automatic electron bridge.

The balance condition of the unloaded bridge is:

$$(R_c + r_1) R_2 = (r_2 + R_x + R_c) R_1. \qquad r_1 + r_2 = R_p. \tag{1}$$

Considering that r_2 has a single value relation to the readings of the instrument let us express r_2 in terms of R_x and R_c from (1)

$$r_2 = k_3R_y - k_4R_x - k_5; \quad k_3 = \frac{R_2}{R_1+R_2}; \quad k_4 = \frac{R_1}{R_1+R_2}; \quad k_5 = \frac{R_1R_c - R_pR_2}{R_1+R_2}. \tag{2}$$

Inserting in (2) $R_c = k_1h_1$ and $R_x = k_2h_2$ we have:

$$r_2 = k_3k_1h_1 - k_4k_2h_2 - k_5. \tag{3}$$

The parameters of the measuring circuit are chosen so that the condition shown below holds:

$$k_1k_3 = k_2k_4. \tag{4}$$

Taking into consideration (4) and that $h_1 - h_2 = H$ expression (4) takes the form:

$$r_2 = cH - k_5. \tag{5}$$

where $c = k_1k_3 = k_2k_4$.

Thus the readings of the bridge are proportional to the level of the melt.

The measuring circuit of the device is fed from a 6.3 or 7.5 v ac source, and relay P_1 from a dc supply. The unbalanced voltage of the bridge is fed to the input of the electron amplifier EA. This voltage is determined by the resistances of the bridge arms, i.e., the ac voltage and that delivered by source $U_=$, i.e., a dc voltage. The dc component is "cut out" by the blocking capacitor C_p at the input of the amplifier and does not affect its operation.

In order to prevent the shunting of the ac resistance of the electrodes by the resistance of the source of voltage $U_=$ and the resistance of relay P_1, a choke coil L is connectedin series with them.

The value of the complementary resistance R_c is chosen in such a manner that the current through relay P_1 is smaller than its operating current when the electrodes are disconnected from the melt, i.e., that in such a case the relay always released.

In this device relay P_1 consists of a polarized relay type RP-4 with a very small operating current, thus providing a low supply voltage $U_=$ and a small dc current through the bridge resistances.

In order to prevent overshoots on the diagram of the automatic bridge at the instant of the electrode disconnections from the melt, the control winding of the reversible motor RM has a normally open contact of relay P_2 inserted in its circuit, so that the opening of the contact stops the motor, but the instrument "remembers" the measurement results.

Conclusions. The measuring circuit of the level indicator was tested out on a cold (water) model of the instrument which made it possible to measure directly the liquid level in the tank. The measurement error was due mainly to the failure to observe accurately condition (4) and to the grade of accuracy of the instrument, which amounted to 1.5% of the maximum level, fixed at 50 cm for this experiment.

When operating with an actual oven the error rises (according to tentative calculations) by a factor of 1.5 to 2.5 due to the additional temperature errors.

The measuring range depends on the electrodes used and can amount to 1 - 1.5 m. The measuring time depends entirely on the servo-motor of the bridge.

The above level indicator can be used for a continuous automatic measurement of the level of metal (slag) in laboratory installations or industrial metallurgical ovens.

LITERATURE CITED

1. V. S. Lerner, "Automation of the electrical smelting of zinc sinter," Theses of Papers Read at the Scientific and Technical Conference on Electrical Heating and in the Zinc and Lead Industry [in Russian] (Moscow, 1959).
2. B. A. Glagovskii, Izmerital'naya Tekh., 10 (1959).

ESSAYS AND REVIEWS

AMERICAN TECHNICAL COUNCIL CIRCUITS FOR CHECKING MEASURING INSTRUMENTS

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 51-54, August, 1960

Information on the system organized by the American Technical Council (ATC) for testing measuring instruments of organizations engaged in the atomic armaments program is published in [1]. The necessity of organizing such a system is due to the rising requirements with respect to accuracy of many measurements, performed in the production of atomic armaments.

TABLE 1

Equipment Used in the Checking Scheme for High Frequencies

Instruments	Frequencies	Time	Permittivity
Basic reference measures and instruments certified by the NBS	Quartz clock of 100 kc, daily instability $\pm 2\cdot 10^{-7}$		Dielectric samples with an error of $\pm$ 0.5%
Reference instruments of lower grades	Quartz calibrator T-2057		Measuring equipment certified in the principal laboratory
	Radio transmitted standard frequencies and precise time signals		
	Timer F-529, error $\pm 10^{-5}$		
	Frequency meters, error $\pm 10^{-6}$	Time intervals meter, error $\pm$ 0.00001 sec. Time intervals meter T-523, error $\pm$ 0.05 sec.	
Working instruments	Quartz generator T-311 and others, instability $\pm 10^{-4}$		Measuring instruments, error $\pm$ 5%
		Time intervals meter, error $\pm$ 0.1 sec.	

The highest metrological agency of the ATC system is its principal laboratory which keeps the secondary standards and reference measures and instruments certified by the National Bureau of Standards (NBS). These standards are of the same quality as first grade standards. The secondary standards are periodically checked

TABLE 2

Equipment Used in the Checking Scheme for Ultrahigh Frequencies

Instruments	Attenuation	Impedance	Power	Dielectric parameters in the range 1000–10000 Mc
Basic and reference measures and instruments certified by the NBS	Reference attenuators, error ± 0.01-0.03 db	Reference loads, error ± 3%	Reference power measuring bridge, power measurement error ± 3%	Dielectric samples, reference equipment error ϵ ± 1%, tan δ ± 2%
Reference instrument of a lower grade	Waveguide attenuators, range of 0-30 db, error ± 0.05 db, and range 30-70 db, error ± 0.25 db. Coaxial attenuators, range 0-60 db, error ± 0.5 db. An equipment for checking and calibrating waveguide attenuators by the substitution method at UHF, range 0-60 db, error ± 0.5 db. Instruments and equipments calibrated in the principal laboratory.	Coaxial and waveguide loads, error ± 5%. Measuring lines, loads and generators calibrated in the principal laboratory.	DC bridge circuit, error in measuring the balancing current ± 0.05% DC bridge, error including the probe ± 6%. Measuring bridges calibrated in the principal or secondary laboratory.	Dielectric samples, error ϵ ± 2%, tan δ ± 3% Measuring equipment, error ϵ ± 3%, tan δ ± 5%.
Working instruments	Measuring equipment, error ± 1-5 db	Measuring equipment (measuring lines, generators, etc), error up to ± 8%	Working bridges, error up to ± 10%	Samples and instruments, checked in the principal and secondary labs

Note. The ranges in measuring ϵ and tan δ are not indicated.

TABLE 3

Certain Instruments for Measuring Frequency and Time

Instruments	Frequency range	Time measuring range	Frequency error	Error in measuring time
Universal time meter Berkeley 5510	0–1 Mc	1 μsec –10⁸ sec	$\pm 10^{-6}\, x \pm 1$ count	$\pm 10^{-6}\, x \pm 1$ μsec*
Recording frequency meter Hewlett-Packard model 524B	0–10 Mc	0.1 μsec –10⁸ sec	$\pm 10^{-6}\, x \pm 1$ count	$\pm 10^{-6}\, x \pm 0.1$ μsec
Hewlett-Packard calibrator, model 540A	100–10000 Mc	–	$\pm 10^{-6}$**	–
Hersch interpolator AM-1	10–1000 Mc	–	$\pm 2 \cdot 10^{-7}$***	–
UHF multiplier Hersch FM-4	100–10000 Mc		$\pm 2 \cdot 10^{-7}$****	
Electrically controlled seconds counter	–	0.05–1000 sec	–	± 0.05 sec
Manually controlled seconds counter	–	0.15–1000 sec	–	± 0.15 sec

* x–the measured value.

** When used with XP-524B.

*** When used with a primary standard or with XP-524B.

**** When used with AM-1 and auxiliary equipment.

TABLE 4

Equipment for Measuring emf, Resistance, Inductance and Capacitance

	DC emf	AC and DC emf	Resistances 0.001-1 ohm	Resistances $1\text{-}10^4$ ohms	Resistances $10^4\text{-}10^8$ ohms	Resistance over 10^8 ohms	Inductance	Capacitance $1\mu\mu f$ to $1\mu f$	Capacitance over $1\mu f$
Basic standards certified by the NBS	Saturated standard cell ± 0.001%	Thermal detector, error ± 0.01%	Reference resistors, error ± 0.002%	Reference resistors, error ± 0.002%	Reference resistors, error ± 0.005-0.05%	Film resistors, error ± 1-2%	Standard coils, error ± 0.03-0.05%	Standard air and mycalex capacitors, error ±0.02-0.05%	Standard capacitors, error ± 0.1%
Reference instruments of a lower grade	Unsaturated standard cell, error ± 0.01% Potentiometers, error ± 0.01-0.015 % Comparators error 0.025% Shunts, error ± 0.04%	Thermal detectors, error ± 0.03% Electrodynamic instruments, error ± 0.25-0.5% Ferrodynamic instruments, error ± 0.75-1% Thermoelectric instruments, error ± 0.75-1%	Standard resistors, error ± 0.02% Potentiometers error ± 0.01-0.015 % Shunts, error ± 0.04% Bridges, error ± 0.04-0.05% Portable bridge error ± 0.2% Decades, error ± 0.5%	Standard resistors, error ± 0.01% Potentiometers, error ± 0.01-0.015% Shunts, error ± 0.04% Bridges, error ± 0.05% Standard resistors and decades, error ± 0.1% Bridges, error ± 0.3%	Standard resistors, error ± 0.1% Bridges, error ± 0.1% Decades, error ± 0.05-0.3% Standard resistors and decades, error ± 0.1% Bridges, error ± 0.3%	Film resistors, electrometers, bridges, error ± 4-8%	Reference measures and comparators checked yearly by the principal laboratory		
							Standard coils, error ± 0.2% Bridges, error ± 0.25-1% Decades of inductances and bridges, error ± 1-2%	Standard capacitors, error ± 0.05-0.1% Bridges, error ±0.2-0.25% Decades of capacitors and bridges, error ± 1%	Standard capacitors, error ± 0.5% Bridges, error ± 1% Instruments calibrated in the principal or secondary laboratories
Working instruments	Instruments with an error ± 1-5%	Instruments with an error ± 2-10%	Instruments with an error ± 0.2-10%	Instruments with an error ± 0.2-10%	Measuring bridges, error ± 2%	Electrometers, ohmmeters, error ± 6-12%	Instruments with an error ± 12%	Instruments with an error ± 5-10%	Instruments with an error ± 5-10%

TABLE 5

Equipment for Measuring Ionizing Radiations

Instruments	Neutrons	Gamma rays
Basic reference instruments, certified by the NBS	Accelerator and reference source of neutrons, error ± 3%	Reference radiometer, error ± 3%
Instruments of lower grades	Reference sources, error ± 4.4%. Equipment certified in secondary laboratories; errors not indicated	Measuring equipment certified in the principal laboratory; errors not indicated
Working instruments	Working equipment, error ± 7.5–30%	Radiation sources, error ± 10%

against first grade NBS standards at varying intervals, depending on the nature of the standards. Work is at hand on the improvement of standards, reference measures and instruments as well as of the conditions of their preservation and upkeep in order to decrease the frequency of their checking. As the result of this work the checking periods of standard resistors, for instance, have been raised from 12 to 24 months, of barometers from 6 to 12 months.

The principal laboratory has two departments, a physical and an electrical. The physical department contains the standards and the reference measures of mass, pressure, humidity, and temperature; the electrical department contains standards and reference measures of electrical quantities for the frequency range of 0 to 10000 Mc.

The laboratories are supplied with high quality equipment. The physical laboratories are kept at a temperature of 20 ± 0.1°C and the electrical at 25 ± 0.5°C. Standards which are seldom used are not made in the principal laboratory; when required,NBS standards are used. On the other hand,new standards are sometimes made which do not exist in the NBS. In particular,a basic power meter for millimeter wavelengths and a reference manometer for reproducing a unit of pressure, based on NBS standards of mass, length and temperature were made at the principal laboratory.

The next link in the checking system of the ATC are the secondary laboratories which are established directly in the plants. The reference measures and instruments possessed by these laboratories are certified in the principal laboratory. This certifying is not equivalent to that of the NBS,but is sufficiently good for practical requirements. The equipment to be calibrated by means of the standards is selected according to the length of its service and the accuracy required. The calibration and checking of instruments is independently done by the secondary laboratories.

Tables are given above of some of the reference measures and instruments which are used in the checking system of the ATS.

LITERATURE CITED

1. H. C. Biggs, IRE Trans. Instrum. 7, No. 3-4 (1958).

MATERIALS RECEIVED BY THE EDITORIAL BOARD

EXPERIENCE GAINED IN REPAIRING INSTRUMENTS IN TRACTOR REPAIR STATIONS

M. D. Kalennikov

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 54-55, August, 1960

The repairing of instruments in collective and state farms, and tractor repair stations, by traveling crews from weighing equipment plants, local industry workshops or other organizations do not produce the expected results. The small, insufficiently skilled crews, separated from their establishments, work in the area as a rule two to three months per year thus dragging out the repair of instruments and often producing work of low quality.

The Kiev State Inspection Laboratory for measuring equipment considers it advisable to organize the repairs of instruments by the Tractor Repair Stations (RTS).*

The repair of instruments by the RTS has unquestionable advantages. The instruments being used in the collective and state farms and RTS will then be attended to, all year round, without any rush and their State checking will be done on request of the RTS workshops.

The repairing of instruments being used in the collective and state farms, RTS and other organizations can be concentrated in the RTS workshops, which would be impossible to do under the old organization of repairs, since the traveling crews come to the areas for a definite period, the weighing equipment repair plants are in the district center, and it is not economically feasible to send crews to collective farms for the inspection of the equipment. The RTS, on the other hand, are close to the collective farms and deal with them constantly, thus being able without difficulty to exert by means of their instrument repair shops continuous supervision of the measuring equipment of collective farms, the RTS and other organizations.

Specialized crews of agricultural workers who are responsible for the measuring equipment can greatly assist the RTS in their work.

The repairing of instruments in workshops attached to the RTS will make it possible to have a constant, technically competent supervision of repairs, to organize the supply of spares and materials, etc.

In exercising technical supervision of the instruments in collective farms, the RTS instrument repair workshops will make a list of all the instruments and will be able to plan without difficulty the required visits to collective farms for the repairing of instruments (including the repair and installation of truck weighing stations and other stationary weighing equipment) and will be able to exercise technical inspection. The mobile RTS instrument repair workshops are especially suitable for the purpose.

The possibility of keeping these workshops occupied all year round is ensured by the fact that in case of a temporary slackness in the shops the available workers can be used for repairing agricultural equipment.

In order to establish a network of such repair workshops, the State Inspection Laboratories should render help in training the RTS mechanics in repairing, adjusting and checking instruments and supplying the workshops with the required reference equipment and instruments.

The weighing equipment repair plants should transfer the reference and other equipment of their traveling crews to the RTS workshops, an operation which can be easily done since both the district agricultural administration and the weighing equipment repair plants are subordinated to the Regional Soviet Executive Committee.

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* See S. I. Gauzner's article in Izmeritel'naya Tekh., 4, 8 (1958) [see English translation].

Last year the Kiev Regional Soviet Executive Committee decided to organize instrument repair workshops attached to the RTS entrusting them with the technical supervision of the instruments in collective farms and other village organizations by means of mutually agreed on contracts.

Instrument repair shops are operating at present in the Kiev region in the Brovaki, Stavishchanny and Ivankovo RTS and are being organized in other RTS.

The RTS instrument repair workshops have been allocated premises, and supplied with the required reference instruments and equipment with the assistance of the State Inspection Laboratories (GKL). The maintenance mechanics have been trained at the Kiev GKL and at the weighing equipment repair plants.

The State checking, inspection and repair of instruments in the areas serviced by the RTS workshops are as yet carried out on the old basis. In the near future, however, in view of the extension of the RTS instrument repair shops, the inspection work in the rural areas will be reorganized. When the inspector visits the areas in the first half of the year, he will enter all the instruments which are below the requirements set by the Committee with respect to their periods of checking, and their technical condition on an appropriate form supplied for the purpose, and will set the time limit for their repairs and submission for State inspection.

The RTS workshops should take part in the further fulfillment of these proposals. If the possibility of influencing the slack owners of the instrument by the RTS, the district organizations and the State inspector himself is taken into account, it is possible to assert that no further inspection will be required. The state of the instruments in the area can be quickly estimated from the inspection forms, state checking and repairs.

The new method of repairing instruments in the rural districts is being organized in all the regions of the Ukraine. By 1961, the Regional agricultural administrations must set up instrument repair shops at all the RTS.

The State Inspection Laboratories for measuring equipment of the Ukrainian SSR have important work ahead of them in organizing the repairs of instruments and supervising them in rural areas. Their task is to render all possible assistance in this respect to the RTS.

SUPPLYING STATE INSPECTION LABORATORIES AND OTHER ESTABLISHMENTS WITH NEW MEASURING EQUIPMENT

I. I. Kogan

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 55-56, August, 1960

The wide application of new measuring techniques should assist considerably the introduction of total mechanization and automation.

In many establishments, state and collective farms of the RSFSR work is in progress for checking the condition of the measuring equipment, tightening up the discipline in inspecting the equipment and its efficient use and the withdrawal from operation of measures and instruments which no longer meet the technical requirements.

The Sovnarkhozer (Councils of National Economy), Regional Soviet Executive Committees and the Councils of Ministers of the Autonomous Republics examine, with the participation of the State Inspection Laboratories (GKL) for measuring equipment, the status of the inspection of measuring equipment by their subordinated organizations and work out plans for improving the technique of measurements, the replacement of obsolete equipment and the introduction of automatic measuring instruments. Special attention is being paid to the repairs of measuring instruments. The Regional Soviet Executive Committees instruct the establishments of local industry to organize the repair of instruments which are mainly used in trade, agriculture, municipal economy, and local industry. The Sovnarkhozes organize the repair of instruments used in industrial establishments of a given economic administrative area. For this purpose, the instruments repair shops are specialized, made to cooperate with

TABLE 1

Estab., measures taken	Time for completion (year)	Instruments marked for assimilation	Ref. instruments and equip. req. for testing instruments marked for assimilation	Availability or lack of ref. instruments in laboratory

TABLE 2

Type of meas. (checking)	List of req. ref. instruments and measuring equip. lacking in the GKL	Req. number of sets	Estab. at which checking takes place	Date by which instruments and equip. are needed

others and some of them combined; the small and medium establishments are assigned for servicing the main establishments, or special instrument repair plants, are created for servicing all the organizations irrespective of their administrative subordination.

On the basis of local requirements, the GKL, with the participation of the Sovnarkhozes, Regional Soviet ECs and the plants work out plans for the development of State inspection of the measuring equipment for 1960-65.

The Voronezh and the Ryazan' GKL have worked out these plans in the best manner. The administration of the Committee for Standards Measures and Measuring Instruments attached to the Council of Ministers of the RSFSR has examined and approved these plans and sent them as models to other laboratories of the republic.

The heads of the Voronezh and the Ryazan' GKL involved in compiling these plans enlist the aid of a wide circle of active laboratory workers and qualified experts in the plants.

At conferences of representatives of the establishments concerned, called by the GKL, these plans were thoroughly discussed.

The seven-year plans of the development of national economy of the given economic administrative area served as a starting point for compiling these plans.

The list of measures to be taken during the period of 1960-65 in connection with the measurement techniques was compiled for all the establishments subordinated to the Sovnarkhoz in the following manner (Table 1).

On the basis of the data thus obtained the GKL compiled their plans for the measuring equipment required for 1960-65 and for the development and provision of state inspection of measuring equipment in the economic administrative area in the following manner, which is based on the areas of measurements involved (Table 2).

After the plan for the development and provision of state inspection of the measuring equipment for 1960-65, had been worked out, the laboratories compiled their yearly plans.

The Committee of Standards, Measures and Measuring Instruments attached to the Council of Ministers of the RSFSR organized conferences of the heads of laboratories at which the plans for the improvement of the measuring technique in the economic administrative areas were discussed.

INSPECTION OF WEIGHING EQUIPMENT

I. R. Rudenko

The specialized establishments of Kaliningrad (the weighing equipment repair plant of the regional local industry administration, the "Rostorgmontazh" combine of the Ministry of Trade of the RSFSR and others) are supervising,according to agreements,the weighing equipment of various organizations.

The sphere of supervision includes trading organizations, public restaurants, local industry plants, medical establishments, communication organizations, etc.

The technical inspectors clean, check and calibrate scales and weights, level them, advise on the correct treatment of scales, check the existence and validity of state stamps and provide the required documents (notes on the certificates of scales and bills for the work done).

Scales of the type of table models, unequal arm, commercial and analytical balances, etc, which have open mechanisms (lack a seal of state inspection) must be dismantled by the mechanic, cleaned and adjusted. Access to dial scales is closed by a state seal and the mechanic cannot inspect them since he has no right to break the seal.

Thus, the cleaning and adjusting of dial scales is excluded, although their error after 3-5 months of operation exceeds the tolerance. The defect could be cleared in 10-15 min, but the mechanic is obliged to send the scales away for repairs. With the 2 year's validity of the State seal,the dial scales (especially types VNTs-2 and VNTs-10) are repaired during 2 years 3-4 times,thus increasing considerably the expenditure on their maintenance. The maintenance of dials, table mounted scales alone,costs the trading establishments on an average 295 rubles 20 kopeks per annum (two repairs and six checks per annum) whereas the maintenance of ordinary table scales costs, for the same period, only 46 rubles 20 kopeks (one repair in 2 years and six checks per year). As the result of this many establishments discontinue the use of dial scales and revert to ordinary scales.

In view of the wide development of technical inspections by mutual agreement, the inspection agencies should be allowed to break the State inspection seals,and after adjustments,place their own seal on the instrument; such seals should be registered at the GKL. In order to know the date of the checking,it is necessary to place in addition to the seal also a date stamp on the body of the scales. Then it will become possible to check dial scales without sending them away for repairs, thus relieving the pressure on the weighing equipment repair plants. The economy thus obtained in the repair of dial scales alone will amount in the Kaliningrad region to 375,000 rubles per year.

ORGANIZATION OF FACTORY AND AREA LABORATORIES

P. U. Markov

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 57-58, August, 1960

The activities of factory test laboratories are being discussed on the pages of "Measurement Techniques"; this is very important since the laboratories are one of the levers which serve to introduce technical progress into the establishments. For improving the work of the laboratories the most diverse methods were suggested (unifying them in a single laboratory, subordinating them to the chief engineer, or the chief technologist, or the head of the Technical Control Division, etc.). We think that the organization of the factory test laboratories cannot be accomplished by a single plan. It is necessary, according to the local condition, to let the Councils of National Economy (Sovnarkhoz) and the area test laboratories determine the structure and subordination of these laboratories.

We think it advisable to share with the readers of this journal our experience in this respect.

At the beginning of 1959,the Tomsk Sovnarkhoz organized an area laboratory for opticomechanical measurements on the basis of the central test laboratory of one of the local plants.

The personnel of this laboratory was supplemented by one engineer and five mechanics-adjusters, who had experience in fitting and gauge work and had completed studies at the special six months course of the Interchangeability Bureau.

If it is found difficult for one plant to assign 5-8 people for this work, other plants should come to the assistance under the guidance of the Sovnarkhoz.

Our area laboratory performs all the functions of a Central Test Laboratory of the plant at which it has been set up: it checks according to schedule all the universal measuring equipment and opticomechanical apparatus; it measures complex details, gauges and instruments, which cannot be checked in the shops; it renders technical assistance to the personnel of the Technical Control Division (OTK) who deals with checking measuring equipment, in the same manner as the department of the chief technologist guides the work of shop technologists; it develops and helps to assimilate new measuring equipment, raises the technical training of the workers and engineers in the use of measuring instruments.

The checking of gauges, their supply and fitting in production is carried out by the OTK.

Should the other laboratories be unified into a department, the area laboratory must remain separated, since the volume of its work in servicing other plants of the Sovnarkhoz is already quite large enough.

Our area laboratory has started servicing the plants assigned to it according to schedule approved by the technical production department of the Sovnarkhoz. The area laboratory does not, as a rule, repair the universal measuring instruments, this remains,as hitherto,the task of the plants.

In addition to the repair and adjusting work the area laboratory must carry out the following work at the plants assigned to it: take part in the development and assimilation of factory plans and schedules for periodic checking of measuring instruments; organize the technical training of workers who use the measures and measuring instruments; develope and improve the technology of repairing and adjusting the measuring equipment and testing machines; compile instructions on the use and preservation of the measuring equipment; rationalize the methods and means of measurement used at the plants; study and test new measuring equipment; take part in the work of the production departments connected with the selection of measuring equipment for production control and take part in the development of technical specifications for the development of the measuring equipment required by the plants; perform the functions of an umpire and consultant on questions of measurement techniques.

The question of the subordination of the area laboratories is of great importance.

Our area laboratory is subordinated to the director of the plant, in which it is located, and to the technical production department of the Sovnarkhoz. The administration of the plant has no right to use the personnel of the laboratory for extraneous work or to reduce its staff without the permission of the Sovnarkhoz.

The question of financial relations with the plants of the Sovnarkhoz are also very important.

In our area laboratory there are laboratory assistants, technicians, engineers, and maintenance mechanics who are on the monthly pay roll, instead of being paid by results. This arrangement improves the quality of repair and adjusting work.and dispenses with the clerical staff in charge of keeping the required records.

Our laboratory is not an independent economic unit. All the payments from servicing the plants are sent to the main accounting department of the plant to which the laboratory is attached.

For the time being, before the establishment of fixed rates for servicing the measured equipment, we charge the customer plants on the basis of wages, time spent and overhead expenses.

The overhead expenses included: the maintenance and servicing of the laboratory-100%; rendering of technical assistance in assimilating and correctly using the measuring equipment, from 20 to 50%; the maintenance of the measuring equipment in a working and accurately measuring state until the next scheduled repair and adjustment (i.e., during one year): for metal cutting and bearing plants-100%, for other plants-50 to 80%.

Thus, the servicing of a plant with 60 opticomechanical units of a total value of some 350,000 rubles costs yearly approximately 35,000-45,000 rubles, i.e., some 10-14% of the total value, which is considerably less than the maintenance and repairs estimated by the accounts department (moreover, the latter estimate does not include the rendering of technical assistance). All this shows that the laboratory is not operating at a loss.

In the future, the serviced plants will pay at the rate of a reduced time charge being worked out by us at the present time on the basis of the VI category of work as listed in the new handbook of piece rates for skilled fitters and turners.

Thus, the servicing accounts will be based on piece work plus overhead charges instead of the hourly rate and overheads, yet the maintenance mechanics will still be paid at a time rate.

The costing of the repair work is a complicated and responsible business. We should like to stress certain peculiarities of this work. In the first place, there are no rates for many types of opticomechanical work. In the second place, the previously existing rates for repair and adjusting work in opticomechanical equipment have been raised by the Interchangeability Bureau for linear and angle measurements. If, on the other hand, the rates cited in the "Foundations for organizing repair and adjusting work in the economic regions" are taken as a basis it will be found that they are calculated for specialized work when the instruments are delivered to the laboratory where engineers and technicians test them and then pass them on for repairs to mechanics; in other words the rates are calculated for mass production conditions whereas in practice this work will be normally carried out by travelling crews or single persons, thus leading to inevitable loss of time and lack of convenient working conditions.

In fixing the rates for repair work it is necessary to include the charges for checking, trouble shooting, etc, since this should be included in the work of the maintenance mechanics.

In introducing the new unified rates for repair and adjustment work in opticomechanical instruments, the newly organized laboratories should be allowed to use during the coming 2-3 years the old rates raised by 15-20%, since otherwise they may encounter financial difficulties.

THE NECESSITY OF ISSUING A REFERENCE BOOK TO STATE INSPECTORS

V. V. Petropavlovskii

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 58-59, August, 1960

The decisions of the Twenty-first Congress of the CPSU and the June (1959) and July (1960) Plenums of the CPSU Central Committee have placed important problems before the personnel of the system of the Committee of Standards, Measures and Measuring Instruments, namely a more effective and efficient help to the establishments for assimilating new measuring equipment and improved methods of measurement, perfecting the quality of production and raising the productivity of labor.

Moreover, regulations 12-58 of the Committee, which were introduced on January 1, 1960, provide for great changes in the procedure of checking and inspection work.

All these circumstances require higher training of the personnel of the Committee's system. The work of the operative personnel of the State Inspection Laboratories (GKL) is mostly done outside the laboratories in the establishments, tractor repair stations (TRS) and collective farms where the inspectors have to deal independently with the most varied problems of a technical and organizational nature.

The technical and reference data, by which the inspector should be guided, is distributed over a wide range of instructions, regulations, operating instructions, specifications, orders, state standards and other materials and sources.

It is impossible to have at hand all these documents. In working outside the GKL, an inspector will, however, experience great difficulties without this data and will risk making involuntary errors by passing rejects.

All these considerations lead to the necessity of compiling and producing a handbook for state inspectors of measures and measuring instruments.

As long ago as 1958, the conference of the active workers of the Committee's system expressed a desire that such a handbook should be published. To date, however, no practical steps are being taken for preparing and compiling such a handbook. During this time, only one question was discussed, namely whether to issue a handbook for workers in the service of measures and measuring instruments only, or for the workers engaged in measurement in general.

It is obvious that the handbook should contain only the data required by the inspector; should be relatively small, of a convenient size, and portable. A handbook for workers engaged in measurements in general, including designers, production workers, repair workers, maintenance staff, the Control, Measuring and Automation Instrument workshops personnel, for measuring laboratories, and the personnel of the measures and measuring instrument service will consist of a volumenous encyclopedia and the material required by the Committee's inspectors will be lost in it.

The handbook of the state inspector can be compiled by the workers of the Committee's system; the draft contents of the handbook should be discussed by the metrological institutes and the GKL for measuring equipment. The discussions should be speeded up so as to make it possible to issue the handbook in 1961.

EDITORIAL NOTE. The editorial board has also received a letter from N. M. Ershov on the necessity of producing a state inspector's handbook.

INFORMATION

A CONFERENCE ON OPTICAL METHODS OF MEASURING LENGTHS AND ANGLES

L. K. Kayak

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 59-60, August, 1960

A Conference on the application of optical methods for measuring lengths and angles was held from June 1 to 4, 1960 in Leningrad, under the auspices of the Leningrad regional administration of the Scientific and Technical Society of the instrument making industry, the D. I. Mendeleev All-Union Scientific Research Institute of Metrology (VNIIM), the S. I. Vavilov State Optical Institute and the Technical and Economic Council of the Leningrad Sovnarkhoz (Council of National Economy).

The conference was attended by more than 250 representatives of scientific research institutes and optical manufacturing plants as well as institutes and organizations which use optical instruments of Moscow, Leningrad, Kiev, Sverdlovsk, Novosibirsk, Khar'kov, and other cities.

At the conference over 30 papers were presented by the VNIIM, the State Optical Institute, the Novosibirsk State Institute of Measures and Measuring Instruments, many leading plants in optical instrument making, and others.

In the papers of Yu. V. Kolomeitsov entitled "Development trends of optical instruments for linear and angle measurements" and of N. F. Delyunov and E. I. Rozenberg on "The State Optical Equipment Plant instruments for linear and angle measurements" modern optical instrument making trends are analyzed and the tasks of the institute and industrial plants for the next few years outlined. A paper on "Soviet optical measuring instruments at the exhibitions in Brussels in 1958 and New York in 1959" was read by A. I. Inyushin. A report on the experience of using Soviet optical measuring instruments in the Kirov plant (Leningrad) was presented by F. P. Volosevich, and com. Druzhinin read a paper on "The application of optical methods for measuring lengths and angles in components and units of medium and large dimensions". All these contributors noted not only the qualities of some of the instruments but also some of their defects and stressed the necessity of greatly increasing the types of instruments produced.

The possibility of extending the range of application of optical instrument was discussed in the papers read by A. I. Kartashev entitled "Optical systems with an increased resolution" and by I. A. Greim entitled "Optical systems with a double scanning of scales for linear and angle measurements".

Many papers dealt with the application of interference methods of measurement.

The papers of N. R. Batarchukova on "Accurate reproduction of the new standard unit of length", of M. L. Brzhezinskii and N. V. Trofimova on "Interference instruments for measuring graduated measures of length" and of A. I. Kartashev on "Interference comparators" have acquired special significance in view of the forthcoming 11th General Conference on Weights and Measures in October 1960 which will deal with the question of transition to the new determination of the unit of length, the meter, expressed in light wavelengths of the orange line of Kr^{86} in vacuum.

The papers read by A. N. Zakhar'evskii, I. I. Dugopel and Yu. V. Kolomeitsov dealt with the production of interference instruments for measuring roughness of finished surfaces, controlling the dimensions and shapes of ball bearing components, and checking the shape of spherical lenses.

Several papers were read on the application of certain achievements of modern physics (electronics, computing techniques, etc) to measurement techniques.

V. P. Koronkevich and Yu. I. Trulev discussed in their papers the application of interference fringe counters for measuring small lengths. The assimilation of photoelectric control methods into measurement techniques was the subject of papers read by A.I. Kartashev, N. P. Batarchukova, and Yu. I. Trulev on "Photoelectric comparators", by A. I. Inyushin, Yu. V. Kolomiitsov, L. E. Korol'kova, G. V. Rodkevich and D. M. Frolov on "Photoelectric methods of controlling the geometrical parameters of optical components" and of Yu. V. Kolomiitsov, V. G. Potupikov and L. E. Korol'kova on "A contactless phase method of measuring the thickness of details".

The successful application of photoelectronics in an objective method of sighting graduations was discussed in the previously mentioned paper by M. L. Brzhezinskii and N. V. Trofimova and in the paper of L. M. Alabovskaya "Methods of measuring angles by means of horizontal and meridional circles".

Work on registering interference fringes by means of photoelectric methods was discussed in the papers of V. P. Linnik, and T. S. Kolomiitsova and of I. V. Novikova, Yu. P. Efremova and Yu. I. Truleva.

Papers on angle measurements were read by G. I. Strakun, M. F. Grechko, L. I. Smirnova, and E. E. Sharova ("An electronic equipment for measuring angles"), by L. A. Nikolaeva ("New Soviet instruments for measuring angles"), by V. P. Golubkova and E. I. Finkel'shtein (Autocollimators of Soviet make and their State testing") and by others. The use of interference for measuring angles was discussed in a paper by V. P. Linnik and G. V. Rodkevich.

In the discussion which followed many critical remarks were addressed to the scientific research institutes and optical instrument manufacturing plants. It was noted that the new designs were put into mass production too slowly, in certain instances the designs of the instruments was not properly completed; they were complicated, large and inconvenient to operate, the application of the new technical devices (electronics, semiconductors, etc) in measuring instruments was timid and slow and the variety of the Soviet-made commercial instrument was not large enough.

Despite the fact that certain mass produced instruments have become obsolete, their modernization has not proceeded with sufficient speed. We are not producing interferometers for measuring end gauges and graduated measures of length, photoelectric microscopes, or raster devices, instruments for checking gears or for measuring details of a complex geometrical form, miniature telescopic sights convenient in operation or autocollimators, high precision angle measuring instruments, etc.

Those taking part in the discussion noted the importance of developing and making small measuring devices which are simple in design yet sufficiently accurate and convenient for fixing on metal working machines, and also the necessity of producing complex, unique, high-precision instruments required in single models for scientific research and precision engineering.

There are no spare units or attachments to the instruments on the market.

The resolution adopted at the conference noted that the Soviet optical instrument industry has reached a high level and is capable of mastering the production of the most precise and perfect measuring instruments.

The conference pointed out the concrete steps required for eliminating the existing defects and determined the most important trends of scientific research and design development for the next few years.

The conference considered it desirable to set up, in Leningrad, an interdepartmental commission for optical measuring instruments for the coordination of scientific research and development, examination of projects for new work, etc.

BRITISH EXHIBITION OF LABORATORY AND INDUSTRIAL INSTRUMENTS

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 60-62, August, 1960

From June 18 to 29, 1960 a British exhibition of laboratory and industrial instruments was held in Moscow in the building of the Polytechnic Museum. The exhibition which was organized by the Association of various British firms, consisted of the latest products of these firms in different areas of measurement techniques (including production automation instruments, instruments used in chemistry, meteorology, optics, metallurgy, electronics, medicine, television, communications, atomic energy and other areas).

The visitors were especially attracted by the digital display and computing instruments, instruments for analyzing gases, liquids and solids, and electrical and radio measuring equipment.

The UHF waveform analyzer of the Airmec Co. can be used at 300 Mc for measuring harmonics, gain and attenuation, as well as for measuring the absolute level down to several microvolts.

The Rank Cintel Co. exhibited three types of bridges for measuring resistance, capacitance, mutual and self-inductance and two types of pulse generators for general use in the pulse technique.

One of the exhibited bridges is intended for measuring mutual inductance or self inductance in the range of 0.001 μh to 30 mh and resistance from 0.001 to 3000 ohms with an error of ± 1%. The measurements are made with an alternating current supplied from a built-in generator of 1592 cps (which corresponds to ω = 10000 rad/sec). The bridge operates from ac mains. It can be used for measuring the inductance of small coils with a low Q-factor at audio frequencies (for instance radio receiver and television coils).

The other bridge serves for measuring capacitance in the range of 0.002–100 $\mu\mu$f and resistance between 1 ohm and 10,000 megohms with an error of ±1%. These measurements are also made at 1592 cps. The instrument can be used for determining inter-electrode capacitances in tubes, cathode-ray tubes, stray wiring capacitances, input capacitances of amplifiers and other electronic equipment.

A dc bridge (operating from ac mains) provides measurements with an error not exceeding ± 1% of resistance in the range of 0.1 ohm to 100 megohm or determines automatically the deviation of resistances from a nominal value. The bridge is especially suitable for production checking of radio components.

The generator provides rectangular signals with a short pulse rise time, a repetition frequency of 1 cps to 1 Mc and a pulse duty factor between 1 : 2 and 2 : 1. The instrument has a built-in resistance which matches the output stage to the load. When matched the instrument has the following output characteristics:

Impedance, ohms	Amplitude, v	Rise time, μsec
75	0.15–5	8
225	5–15	25
270	15–50	50

The same company exhibited a microsecond chronometer-computer for measuring time intervals of 1 μsec to 1 sec or from 10 μsec to 10 sec. Electrical voltage pulses of 10-40 v serve as input signals in the instrument. The time is recorded on 6 dials, each of which is calibrated from 0 to 9; the measurement error is ± 0.005%.

The Salatron Co. exhibited oscilloscopes, and precision electronic instruments, including ac millivoltmeters, wide range oscillators, signal generators, capacitance and frequency measuring devices, pulse and rectangular wave generators. Of the digital display voltmeters, one should note voltmeter LM.902.2 with a range of 0.1 mv to 1599 v and an error of 0.1%, and an ac rectifying voltmeter LM.903 which measures ac voltages from 0.01 mv to 159.9 v (on 5 scales) in the range of 20 cps to 5 Mc and provides similarly to the LM.902.2 instrument a digital display reading.

The firm also exhibited a transfer function analyzer which makes it possible to investigate the dynamic characteristics of electrical, hydraulic, pneumatic and mechanical systems.

The low-frequency decade generator type OS 103.2 which covers a range of 0.01 cps to 11.1 kc in 4 bands with a frequency error of ± 1.5-2% and provides an output voltage with four different phases (spaced by 90°) was also exhibited by this firm.

The firm also showed single and double beam oscilloscopes.

Racal Instruments Limited showed an interesting digital-display frequency meter type SA21A which measures in the range of 10 cps to 1 Mc with an accuracy of ± 1% of the reading. An auxiliary device can convert the frequency meter readings into the required digital form or operate a printing device.

A digital display instrument of the same firm intended for commercial measurements evaluates ac and dc voltages, resistance and capacitance in a digital-display form with an automatic determination of the polarity.

Of the W. G. Pye Company's instruments one should note the precision decade potentiometer (catalog No. 7600). The instrument is simple and convenient to use. The decade switches.with a very low and constant contact resistance, developed by the company, obviate the use of slide wires. The total resistance of the potentiometer switches amounts to some ± 0.7 megohm. All the figures are in a straight line and easy to read without making mistakes. The range of the instrument is from 1.99999 v to 1 μv. The error of measurements is ± 0.002%, and the error in comparing two voltages is ± 0.001%.

Electronic Instruments Ltd. exhibited various instruments for measuring resistance in the range of 10^{-4} to $5 \cdot 10^{15}$ ohms; including milliohmmeter 47A for measuring four digit resistors from 50 microhms to 1200 ohms (in 7 ranges), with an error of ± 2% of the full scale deflection; a megohmmeter type 35 for measuring resistances from $5 \cdot 10^{4}$ to $2 \cdot 10^{11}$ ohms (in 9 ranges at 100 and 500 v) with an error of 1.2%; a million megohms meter type 29 for measuring resistances from $3 \cdot 10^{5}$ to $2 \cdot 10^{13}$ ohms (in 11 ranges at 85, 150, and 500 v) with an error of ± 2–6% of the measured value, depending on the range; a million megohms meter type 31A for measuring resistances from 10^{7} to 10^{14} ohms (in 7 ranges at 1, 10 or 100 v) with an error of ± 1% (up to 10^{12} ohms) and ± 2% (up to 10^{14} ohms). All these instruments operate from ac 127 or 220 v mains.

The company also exhibited an electrometer type 33B which measured in 5 ranges voltages from 10 to 1000 mv with an error of ± 1% of the full scale deflection ± 0.1 mv and a zero drift not exceeding ± 0.1 mv in 12 hours, the input resistance of the instrument is 10^{13} ohms (this makes it possible to use the instrument for measuring small currents, large resistances and hydrogen ion concentrations, pH); electrometer 33C with characteristics similar to the preceding model but an input resistance of 10^{16} ohms has a zero drift of ± 0.3 mv in a week, after stabilization of its operation (when fed from ac mains).

The same company exhibited pH-meters for commercial, laboratory and medical use. The 28AM pH-meter for commercial use has ranges of 0–7, 0–10 and 0–14 pH. The stability of its readings amounts to ± 0.02 pH in the first day of its operation and to 0.1 pH thereafter, irrespective of time. The C33B pH-meter has a range of 3 to 10 pH,a sensitivity of 0.002 pH and stability of ± 0.002 pH in 12 hours.

The W. G. Pye Co. has also shown pH-meters including the "Dynacap" instrument (catalog No. 11072) with ranges of 0–10, 4–14, 0–2, 2–4, 4–6, 6–8, 8–10, 10–12,and 12–14 pH with a calibration of the "extended" scales of 0.02 pH per division and an input resistance of 10^{11} ohms; the instrument mark "H" (catalog No. 11530) has a range of 2–12 pH and an error of ± 0.02 pH; the instruments operate from ac mains.

The Cambridge Instrument Company exhibited a miniature pH-meter with a range of 0–14 pH and an error of ± 0.1 pH; the instrument operates from built-in dry cells which supplies it for 1000 hours; its dimensions are 22.8 x 10.1 x 7.6 cm and its weight is 1.25 kg.

The Edwards Company exhibited instruments for measuring vacuum: a device for controlling the emission of ionic current and an amplifier in conjunction with the head of an Alpert manometer type IG3 that can measure vacuum down to $5 \cdot 10^{-11}$ mm Hg, the miniature Pirani B4 manometer intended for measuring vacuum from 0.5 to 0.001 mm Hg and an ionization Pening manometer that measures in the range of 10^{-2} to 10^{-5} mm Hg.

Level indicators and flow meters were exhibited by Fort Cleveland Instruments. The electronic instrument used in oil-refining plants measures the level of liquids in tanks with an error of 0.4 mm, and a Gilbarco remote measuring receiver indicates levels of several tanks in turn (up to 30). Flow meters of the turbine type that can be used for measuring the flow of various pure liquids from 7 to 500000 g/min.

Among the exhibits of E. M. I. Electronics Limited there was a stroboscope with a frequency of flashes exceeding 30000 per minute and a hand stroboscope with a flash frequency of 600 to 6000 per minute.

A large number of instruments for physicochemical research and production control of liquid and gaseous substances were also exhibited. Among them the Griffin and George chromatograph should be noted. Instrument PVX type 11B can be used for analyzing mixtures of hydrocarbons of compositions C_1-C_{24} in their boiling range from 0 to 400°C at atmospheric pressure. The analysis results are recorded by a Honeywell electronic potentiometer with a range of 1 mv and a scale traversing time of 1 sec.

Polarimeter type S34-410 made by the same firm can be used both with monochromatic and white light with a half-shade angle of about 10°. The instrument is designed for tubes, containing solution, from 100 to 200 mm long. The tubes can be set by a controlling device parallel to the optical axis.

A fluorite vacuum polychromator Polyvac 4 made by Hilger and Watts is intended for automatic analysis of nitrogen, phosphor and sulfur in steel. Its reversible dispersion at 1775A is 6A/mm; and the spectral length at 1600 to 1850A is 52 mm. A polychromator with a three-meter grating, produced by the same firm can analyze 30 elements in a compound alloy in 4 min. The photomultipliers can have 51 set positions. The grating has a radius of curvature of 3 m. The reversible dispersion is 6 A/mm (or 3 A/mm with a finer grating) and the range approximately 1940 to 8000 A.

Colorimeter J40 of the same firm is intended for measuring surface coloring of various materials including powders and liquids. This firm also exhibited an interferometer made to the National Physical Laboratory specification intended for measuring gauges 10 cm long. It is possible by means of this instrument to measure 18 gauges of various dimensions simultaneously with an accuracy up to 0.025 μ.

This company also makes instruments for measuring external dimensions from 0 to 340 mm and to 1 m with an error of 0.1 and 0.2 μ respectively, and internal dimensions from 1 to 255 mm with an error of 0.1 μ.

The Hilger and Watts automatic levelling instrument is supplied with a stabilizer which automatically sets and maintains a horizontal line of sight. Its error is 1 mm in 1300 m.

The two vertical mechanical comparators of the Sigma Instruments Company provide magnifications of 5000 and 3000. One of the instruments is supplied with a universal device intended for measuring cams and deviations from a cylindrical form. Among their electrical comparators, one provides a magnification of 50,000 and the other multiscale instrument magnifications of 10,000, 15,000, and 30,000.

The same firm also exhibited a dynamometer for cutting tools which recorded the cutting effort in 3 directions on medium-sized lathes. By means of this dynamometer it is possible to measure the radial, axial and vertical loads.

Among the digital display counting instruments, computer type 803 made by Elliott Brothers should be noted. This computer memorizes 140 signs per second on a paper tape and produces 25 signs per second, but it can supply a further 300 cards per minute by means of a read-out device. The command code is designed for 64 operations, all of which, with the exception of multiplication and division, are performed in one period of time equal to 0.72 μsec. Multiplication and division take up 29.6 μsec. Its memory consists of 4096 cells which retain 39 binary numbers.

Stanton Instruments Limited demonstrated various analytical balances, including single-pan scales and scales for measuring precious metals. The thermorecording balance TR-1 consists of a precision analytical balance and an oven with a recording device. The instrument records very small variations in the weight of samples placed in the oven and caused by temperature changes with time. The oven is supplied with a programming regulator. The instrument is used for checking analytical methods, investigating corrosion, oxidation and catalysis, and for testing fuels.

The Electrothermal company exhibited original heating jackets of various types, including jackets in aluminium containers for bulbs of a capacity of 50 ml to 10 liters, as well as jackets for several bulbs and funnels of various sizes.

Various types of titration meters were exhibited by the Baird and Tatlock company.

The Cambridge Instrument company exhibited an original automatic electronic potentiometer for multicurve recording. This instrument provides sequential recording of 400 distinct measurements in the form of a straight line on a chart with a simultaneous coding of the numbers of each measurement on the left-hand side of the chart. The same firm exhibited various automatic single and multicurve recording potentiometers, including high-speed potentiometers and other electrical measuring instruments in various areas of measurements.

Cossor Instruments Limited exhibited single and double beam oscilloscopes.

In a specially equipped hall at the exhibition leading specialists of the exhibiting firms gave lectures and read papers on the instruments used in various spheres of measurements and provided required information. Catalogs and prospectuses on the exhibited instruments were provided.

B. R. and M. Sh.

INDUSTRIAL EXHIBITION OF THE HUNGARIAN PEOPLE'S REPUBLIC

Translated from Izmeritel'naya Tekhnika, No. 8, p. 62, August, 1960

From August 12 to September 4, an Exhibition of the Hungarian People's Republic was held in Moscow.

The instrument making industry is well represented at the exhibition. Among other instruments, those for measuring radiations equipped with transistors, counters of light pulses, laboratory counters and other instruments were exhibited.

A. N. BOIKO

Translated from Izmeritel'naya Tekhnika, No. 8, p. 63, August, 1960

One of the oldest members of the staff of the D. I. Mendeleev All-Union Scientific-Research Institute of Metrology, Alexis Nikitich Boiko, died on May 20, 1960.

Alexis Nikitich was born of a peasant family in 1885. Having completed his studies in the Petersburg Polytechnic Institute in 1914 he started work in the Physicotechnical Institute, and in 1918 began to work at the principal Chamber of Weights and Measures, now the D. I. Mendeleev All-Union Scientific-Research Institute of Metrology (VNIIM).

Combining happily his brilliant engineering education and the experience of a physicist-experimenter, gained under the guidance of Academician A. F. Ioffe, A. N. Boiko organized with great enthusiasm and efficiency the laboratory of permanent magnets.

When the Soviet instrument-making industry was being built up, A. N. Boiko rendered great assistance in organizing the production and quality checking of permanent magnets in the Kozitskii plant and the "Krasnaya Zarya", "Krasnyi Oktyabr' " and "Elektrostal' " factories.

Research in this area of magnetism, which was started by A. N. Boiko when he was still a student, led him to the interesting work of establishing the theory of the field structure of permanent magnets.

In addition to the work on the technique of magnetic measurements and the production technology of magnetic materials Boiko's scientific activities also included research in the areas of photoelectric elements, and rare gases which he conducted not only in the USSR but also in foreign laboratories. As a result of this research two helium laboratories were organized in Leningrad and one actinometric laboratory in the VNIIM.

A. N. Boiko's research in actinometry was closely connected with balneology, phototherapy and climatology, in which Alexis Nikitich worked over 30 years and became an outstanding specialist.

A. N. Boiko's most interesting research from the metrological point of view consisted in developing objective methods of measuring ultraviolet rays and other radiations.

A. N. Boiko devoted great attention to the development of the All-Union Scientific-Research Institute of Physico-Technical and Radiotechnical Measurements.

Alexis Nikitich developed 28 original instruments and published 30 scientific works.

Boiko's charming personality, understanding and comradeship commanded the respect of all his colleagues in the VNIIM.

V. O. Arutyunov, A. K. Kolosov, E. T. Chernyshev, E. G. Shrankov, and B. M. Yanovskii

COMMITTEE OF STANDARDS, MEASURES AND MEASUREMENT INSTRUMENTS

I. NEW SPECIFICATION FOR MEASURES AND MEASURING INSTRUMENTS APPROVED BY THE COMMITTEE

NEW STANDARDS

(Registration of June, 1960)

Translated from Izmeritel'naya Tekhnika, No. 8, pp. 63-64, August, 1960

GOST 1774-60. Screw gauges, fixed. Length of thread. Replacing GOST 1774-42.

GOST 6570-60. AC electricity meters. Replacing GOST 6570-53.

GOST 9468-60. Pneumatic instruments and automation equipment. Input and output parameters.

GOST 9469-60. Recording instruments. Clock-work drives.

NEW INSTRUCTIONS ON CHECKING MEASURES AND MEASURING INSTRUMENTS

(Registration of March-July, 1960)

Instruction 1-60 on checking reference weighted piston manometers grades 2 and 3 with a range of 50 to 2500 kg-wt/cm^2. Replacing instruction 1-54.

Instruction 159-60 for checking liquid in glass thermometers. Replacing instruction 159-54.

Instruction 187-60 for checking galvanometers. Replacing instruction 187-54.

Instruction 188-60 for checking ohmmeters and faradmeters. Replacing instruction 188-54.

Instruction 195-60 for checking electricity meters. Replacing instruction 195-54.

II. SPECIFICATIONS FOR CHECKING MEASURES AND MEASURING INSTRUMENTS APPROVED BY THE MEASURING INSTRUMENTS' ADMINISTRATION OF THE COMMITTEE

(Registration of June, 1960)

Specification No. 178 for checking measuring receivers with a high impedance input and field-strength measuring sets with frame antennas.

III. MEASURES AND MEASURING INSTRUMENTS APPROVED BY THE COMMITTEE AS THE RESULT OF STATE TESTS AND PASSED FOR USE IN THE USSR

(Registration of July, 1960)

Thermoelectric voltmeters, trade mark T16, of the Leningrad Council of National Economy (Sovnarkhoz), State register No. 1364-60.

Thermoelectric voltmeters, trade mark T17, of the Leningrad Sovnarkhoz. State register No. 1365-60.

Portable galvanometers, dial indicating, trade mark M196, of the Leningrad Sovnarkhoz, State register No. 1366-60.

Pulse-measuring tube voltmeters, trade mark VLI-3 of the Estonian Sovnarkhoz. State register No. 1367-60.

Refractometers, trade mark IRF-23 of the Tartar Sovnarkhoz. State register No. 1368-60.

Optical pyrometers, trade mark OPPIR-017, in two versions, one with a range of 800-2000°C and the other 1200-3200°C of the Kaluga Sovnarkhoz. State register No. 1369-60.

Infrared color pyrometers, trade mark PIRSO-1 with a range of 600 to 1400°C of the A. A. Baikov Institute of Metallurgy of the Acad. Sci. USSR. State register No. 1370-60.

Rack-mounted ammeters, trade mark M-762 of the Krasnodar Sovnarkhoz. State register No. 1371-60.

Rack-mounted voltmeters, trade mark M-762 of the Krasnodar Sovnarkhoz. State register No. 1372-60.

Measuring lines, nominal designation LI-5 of the State Committee for Radio-electronics. State register No. 1373-60.

Gasolene pumps, trade mark M-3107 of the Moscow Regional Sovnarkhoz. State register No. 1374-60.

Cable measuring bridge, trade mark R-334 of the Krasnodar Sovnarkhoz. State register No. 1375-60.

Glue meters of the Moscow Regional Sovnarkhoz. State register No. 1376-60.

IV. MEASURES AND MEASURING INSTRUMENTS EXCLUDED FROM THE STATE REGISTER

Microammeters MA-750/5. State register No. 521.

Mirror galvanometers GZS-47. State register No. 643.

Mirror galvanometers GZP-47. State register No. 910.

Portable ammeters MA-11. State register No. 911.

Volt-ammeters, portable MVA-47. State register No. 951.

Portable voltmeters V-1500. State register No. 952.